Title
Annotated Bibliography 1951-2001

Author
Hopland Research & Extension Center

Publication Date
2003-06-04

RESEARCH AT HOPLAND: 1951-2001
AN ANNOTATED BIBLIOGRAPHY

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UNIVERSITY of CALIFORNIA
Agriculture &
Natural Resources

Hopland Research and Extension Center
Publication 104

June 2003

Library of Congress Catalog Card Number: 96-75126

Additional copies of this publication may be ordered from the address below for $10.00 per copy (check payable to: *Regents, University of California*) to defray printing, shipping, and handling.

Publications
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Headquarters office and laboratory, 1998

Guy E. Connolly

Field Station entrance and Niderost Barn, Summer 1974

Introduction

The University of California's presence in southeastern Mendocino County dates from the purchase of the Roy L. Pratt Ranch on July 1, 1951. This land, which became the Hopland Field Station, originally encompassed 4,630 acres of North Coast rangeland, historically the most important sheep-raising region in California. A subsequent transfer of additional high-elevation acreage from the Bureau of Land Management to the University in the 1960s increased the station's size to the present 5,358 acres.

Action that led to the field station's establishment occurred at the September 20, 1950 meeting of the Regents of the University of California. At that time, they unanimously approved the concept of establishing a field experiment station within the College of Agriculture to investigate problems pertaining to the conservation and use of the natural resources represented in some 30 million acres of California rangeland. Terms of the initial purchase were $135,000 for the land, and $65,000 for the buildings– including 3 residences and several barns, equipment, supplies, and 1,135 head of sheep that came with the ranch.

Preliminary study of the need for such a facility was accomplished by a Range Land Utilization Committee in the UC College of Agriculture, headed by B. A. Madson of the Department of Agronomy, UC Davis. It was on the basis of these defined needs that the Regents took action. The committee stated,

> "Very little work has been done on range management problems, the answers to which are essential to determine how a range must be handled in order that it may be maintained in a productive and improved condition. These latter types of investigations must be carried on under carefully controlled conditions and for a long period of time. It is for these studies in particular that a range experiment station is required.
>
> "While the production of feed for livestock has been and often is regarded as the primary purpose of these range areas, they have other uses and values which must be considered, i.e. production of game and other wildlife, recreation, and watersheds. These multiple uses pose problems that have received but little attention and on which very inadequate information is available...
>
> "Many of the important problems will require the coordinated effort of several divisions of the College over a considerable period of time, and such work can be effectively done only on a permanent site."

The large volume of research accomplished at Hopland, summarized here, is a testimony to the foresight of those who envisioned, located, built, and developed the facility that is now known as the Hopland Research and Extension Center. Over a half-century, some 1,220 publications, included here, have been identified as being directly the result of the Hopland facility's existence– an average of more than 24 publications per year.

The return on the investment of time and money made by the University and its cooperators is increased knowledge, which is only briefly summarized within this document. Some of the new knowledge received immediate application, not only in North Coastal California, but statewide, nationwide, and worldwide. Other information obtained has had less immediate application, but no less value in terms of human

understanding of biological, geological, and physical processes. Further, many dozens of undergraduate and graduate students have called this facility "home" for a portion of their academic careers. In doing so, they have not only contributed to scientific progress, but they have gained experience, confidence, and wisdom in ways that cannot be readily measured from working with researchers and with Center staff. This publication cites nearly 50 Masters theses and Doctoral dissertations that have utilized Hopland's facilities and resources.

A quick review of this bibliography reveals several areas of research that have received emphasis and have been significantly productive over more than five decades: sheep biology and management; range improvement, particularly emphasizing vegetation management and soil fertility; wildlife science, with particular attention to Columbian black-tailed deer and to coyotes; and entomology, parasitology, and disease, with emphasis on species of public health and veterinary significance. For example, approximately 14 tick-borne microbial agents have been detected in or isolated from wildlife or ticks at Hopland. Of these, 7 are proven or suspected causative agents of human or livestock diseases. These include the micro-organisms that cause Lyme disease, tularemia, Rocky Mountain spotted fever, ehrlichiosis, and Q-fever as well as a Colorado tick fever-like virus. Notably, the first isolate of the Lyme disease spirochete from western North America was obtained from a tick collected at Hopland in 1984. Lyme disease is now recognized to be the most important arthropod-borne disease in California, the United States, and in other temperate regions of the world.

The Subject Index, found on pages 249 through 277, offers a glance at the diversity of subjects studied at Hopland. Many of the studies have been interdisciplinary in nature, resulting from a team effort of scientists and managers with diverse specializations. Watershed studies initiated in 1955, for example, have had components and cooperators that include studies of geology, hydrology, agronomy, range science, plant ecology, and plant physiology. A similar mix of disciplines came together to undertake brush management studies at Hopland, also beginning in the mid-1950s. The information compiled through such studies not only soon provided a basis for revised management recommendations, but it also contributed to basic knowledge about physical and biological processes.

A research location of this type, to which an institution has made a long-term commitment, offers opportunities for long-term and controlled studies that are not generally found in the private sector. Professor Norman F. Baker describes the value of Hopland as follows:

> "...during the 1950s and 1960s Hopland was considered one of the foremost stations for evaluation of chemicals as anthelmintics in sheep. From my point of view the principal reason for this was our unique ability to obtain lambs year after year with similar breeding, parasite exposure, and parasites of restricted origin giving us a basis for year-to-year comparison. The validity of the continued source of lambs was confirmed by utilizing a single control batch of phenothiazine year after year and confirming no significant differences in worm species and/or susceptibility to phenothiazine. This was a contribution of the Hopland Field Station appreciated by pharmaceutical companies as well as persons at the Food and Drug Administration."

In addition to its values to researchers, this facility has also served as an educational center where growers, technicians, land managers, public interest representatives, and students have had the opportunity to view the progress of research and to interact with researchers. In addition to many tours, workshops, and field days, Hopland has attracted a mix of visiting scientists from around the world who have come not only to obtain but also to share information. It is impossible to quantify the educational benefits realized by these visitors, recently numbering in excess of 1,000 per year.

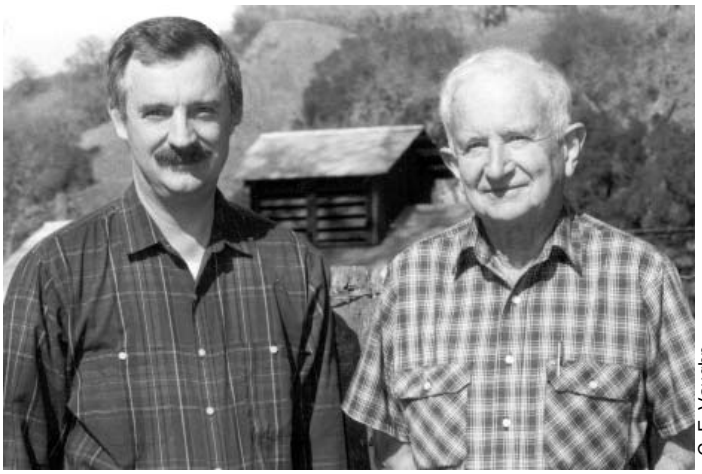
This bibliography is divided into five major subject areas: Animal Science; Entomology, Parasitology, and Disease; Plant Science and Ecology; Range Management; and Wildlife. A few miscellaneous publications are grouped into the section "Other Subjects." Many publications are interdisciplinary in nature and could

logically fit into two or more categories; however, we have placed each citation within only a single subject section, in order to avoid duplication. The Subject Index can assist the reader in searching for all pertinent publications dealing with a specific topic.

Much of what has been discovered over the past years provides an important database for current and future research. Investigators exploring the potential for new research at Hopland are often astounded by the available information on hand– a half century of weather data, sheep performance trends, predation incidence, wildlife inventories, soil analyses, pasture production and improvements, and so on. The University's facility at Hopland is, in a word, irreplaceable. The directions that research may take in future years are perhaps unpredictable. Yet, it is almost certain that the Hopland Research and Extension Center will continue to be a highly productive facility for scientists exploring a diversity of subjects.

Alfred H. Murphy
Superintendent, 1951 - 1986

Robert M. Timm
Superintendent, 1987 -



C. E. Vaughn

Bob Timm and Al Murphy, Spring 1997

Acknowledgments

This annotated bibliography was made possible by funds provided by the Research and Extension Centers Administrative Office (Fred Perry, Director); the former North Region, UC Division of Agriculture and Natural Resources (Terry Salmon, Director); and by Robert S. Lane (UC Berkeley).

The following individuals graciously served as reviewers of the major sections of this publication:
Animal Science - G. Eric Bradford
Entomology, Parasitology, and Disease - John R. Anderson
Plant Science and Ecology and *Range Management* - Alfred H. Murphy and Charles E. Vaughn
Wildlife - Guy E. Connolly

Thanks are also expressed to those authors who reviewed citations of their own publications and accompanying abstracts for accuracy and completeness:
Theodore E. Adams Jr., John R. Anderson, Norman F. Baker, G. Eric Bradford, James W. Bartolome, William H. Brooks III, Guy E. Connolly, Harold F. Heady, Walter E. Howard, Walter L. Graves, Milton B. Jones, Robert S. Lane, William M. Longhurst, James H. Meyer, John W. Menke, Dale R. McCullough, Alfred H. Murphy, Edward O. Price, Vincent V. Resh, Kevin J. Rice, Randall E. Rosiere, Joseph J. Schall, Jerry H. Scrivner, Ahmed E. Sidahmed, Donald T. Torell, Charles E. Vaughn, Jan O. Washburn, Clarence J. Weinman, William C. Weir, and William A. Williams.

This bibliography is largely based on an earlier compilation of the Center's publications maintained by Superintendent Al Murphy with the secretarial assistance of Dale Elkins, Barbara Weiss, and Nancy O'Ferrall. Jane Rohrbough, Amber Shrum, Barbara Butler, and Sue Murphey put considerable effort into organizing the Center's archives of original publications, as well as assisting in development of the database of publications. Amber Shrum and Jane Rohrbough further assisted in finalizing this publication by many hours of proofreading, scanning photographs, and preparing camera-ready pages for the printer. The completion of this project would not have been possible without the able assistance of Jennifer Terwilliger, a 1999 summer intern who devoted her time and energy to this project.

We regret that we do not know the source of all photographs included herein. Wherever possible, we have credited the photographer whose photos we have included, and we express our appreciation to all those who have documented research and extension efforts at Hopland through their photography.

R.M.T.
C.E.V.

Editors' Note

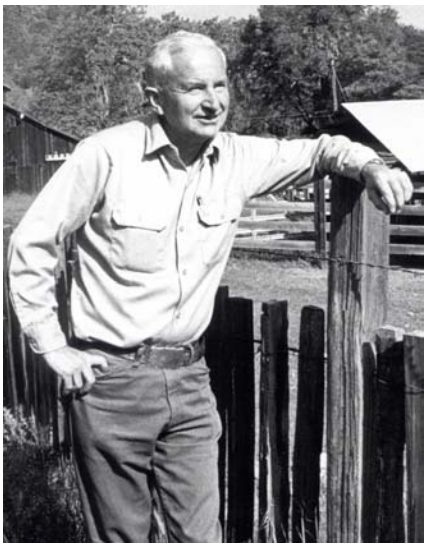
In compiling this Annotated Bibliography, we have endeavored to include all known publications resulting from field research conducted at Hopland, and from educational events held at the Center (workshops and symposia), with publication dates 1951 through 2001. Also included are certain publications authored or co-authored by faculty or staff who were located at the Hopland Research & Extension Center, even though these publications may not directly reflect field research conducted at the Center. The rationale for including the latter publications is that these are products of scholarly effort that resulted from the Center's existence and from the efforts of personnel at this facility.

In the citations and abstracts included here, we have used the original scientific names for species as they were stated by the publications' authors. Some species names have changed over time, and where possible, we have cross-referenced these changes in taxonomic nomenclature in the Subject Index.

A searchable database containing the citations in this publication is also maintained on the Center's web site, which can be accessed at **http://danrrec.ucdavis.edu/hopland/home_page.html.** We anticipate that new citations will be added to this web-based database annually. An additional source of information on recent work at Hopland is the November/December 2001 issue of *California Agriculture* (Vol. 55 No. 6). This issue was devoted to reports of research done at this Center, in celebration of the Center's 50th anniversary.

To increase the usefulness and accuracy of future revisions of this publication, and to assist us in maintaining our database of research publications, we encourage readers to inform us of needed corrections or additions.

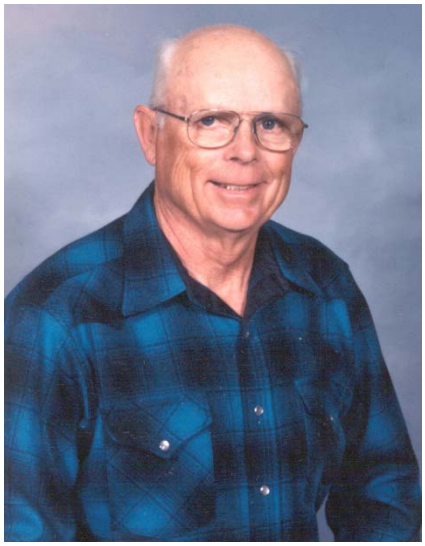
In Memoriam



Tracy Borland

Alfred H. Murphy
Apr. 14, 1918 - Dec. 22, 2001

Superintendent, Hopland Field Station
and
Specialist in the Agricultural Experiment Station,
Department of Agronomy & Range Science,
UC Davis
1951 - 1986



Francis C. Lile
May 25, 1933 - June 19, 2003

Principal Superintendent of Agriculture,
Hopland Field Station
1961 - 1991


Hopland

Descriptive Information:

Hopland Research and Extension Center

Division of Agriculture & Natural Resources
University of California

History and Mission

The land now comprising the Hopland Research and Extension Center (HREC), following centuries of use by Native Americans, was owned by a number of pioneer settlers who came to the Sanel Valley of North Coastal California in the 19th Century. Roy L. Pratt, an executive of the Del Monte Corporation in the Monterey area, subsequently purchased a number of these landholdings and the resulting "Pratt Ranch" was used by him and his family for recreation, while also functioning as a working sheep ranch. The site was one of several properties in southern Mendocino County investigated by a committee of UC academics who in 1950 began seeking a site for a research field station in the north coast area. The Pratt Ranch was subsequently purchased by the Regents of the University of California, in order to establish the Hopland Field Station.

Currently, the Center is one of 9 such facilities located throughout California's various crop production and climatic zones. The system of Research and Extension Centers is operated by the Division of Agriculture and Natural Resources, and as such the Centers are a unit independent from any single UC campus. The three main purposes of the Research and Extension Centers are:

- To provide University researchers with the opportunity to conduct research in climatic zones and in commodities best suited to their individual research discipline or responsibility;
- To provide University personnel the opportunity to research solutions for important regional problems; and
- To extend the results of research to regional clientele and industries so they may put the new information into day-to-day application.

Because of its location and resources, HREC has historically been most heavily utilized by faculty and students from UC Berkeley and UC Davis, as well as by Cooperative Extension advisors who are located in Mendocino County and adjacent counties.

Natural Resources

The Center, with more than 5,300 acres, provides rich opportunities for study of natural resources and related agricultural research, especially on topics pertinent to rangelands of the central and north coast of California. Elevation ranges from 500 feet above sea level, on the floor of the valley near the Russian River and East Hopland, to slightly over 3,000 feet on the Center's east boundary with the BLM Cow Mountain Recreation Area, at the border between Mendocino and Lake Counties.

Soils: Geologically part of the Franciscan formation, soils are mostly sedimentary material and are quite variable, with 17 soil series recognized. A detailed soils map of the Center was completed and published in 1958.

Plant Communities: Four principal vegetation types (grass, woodland-grass, dense woodland, and chaparral) include more than 800 species and cover 95% of the Center's acreage. The Center maintains a herbarium collection that is one of the most complete repositories of plant materials in the north coast region. Divided into more than 30 fenced pastures, most of the Center's rangeland is grazed annually by sheep. Approximately 20 acres are managed as grazed irrigated pasture. However, livestock has been excluded from several "biological areas" set aside since the mid-1950s to serve as controls for evaluation of grazing impacts. These total approximately 460 acres. One parcel of approximately 7 acres has been fenced to exclude both livestock and deer since about 1957.

With an unusually diverse array of native oak species, oak woodland management has received considerable attention since the mid-1980s, with emphasis on sustainable management of valley oak and blue oak. Protection and restoration of riparian corridors has also received increased focus; sections of a corridor along Parsons Creek have been fenced to exclude sheep or sheep and deer. The recovery of native vegetation along these sections in less than a decade of protection is dramatic and has significantly improved habitat for wildlife and for fish.

Wildlife: The Center supports more than 200 species of birds, 40 mammals, 27 reptiles and amphibians and 8 fish, including steelhead trout that spawn in Parsons Creek, a tributary of the Russian River which has its headwaters on the Center. Historically, the Center's Columbian black-tailed deer herd has received intensive study, making it one of the best-studied deer populations on the West Coast. Because of their continued impact on the Center's research sheep and lamb flock, coyotes have been the subject of many studies designed to find new methods to solve this conflict.

Climate

Characterized by hot, dry summers and mild, rainy winters, the Center's Mediterranean climate varies somewhat according to elevation and aspect. Rainfall normally occurs between October and May, with 75% of the precipitation received from November through February. Annual precipitation averages 37 inches at 800 ft. elevation and 45 inches at 3,000 ft. Snow is infrequent, usually present at the upper elevations and generally not lasting more than a few days. Annual mean temperature at 800 ft. elevation is 57°F; mean average temperature July through September is 70°F, while the mean maximum is 92°F. Mean average temperature December through February is 45°F. The frost-free growing season averages 250 days. The Center maintains climatic records from five weather stations at differing elevations, with some records extending from 1951.

Agricultural Resources

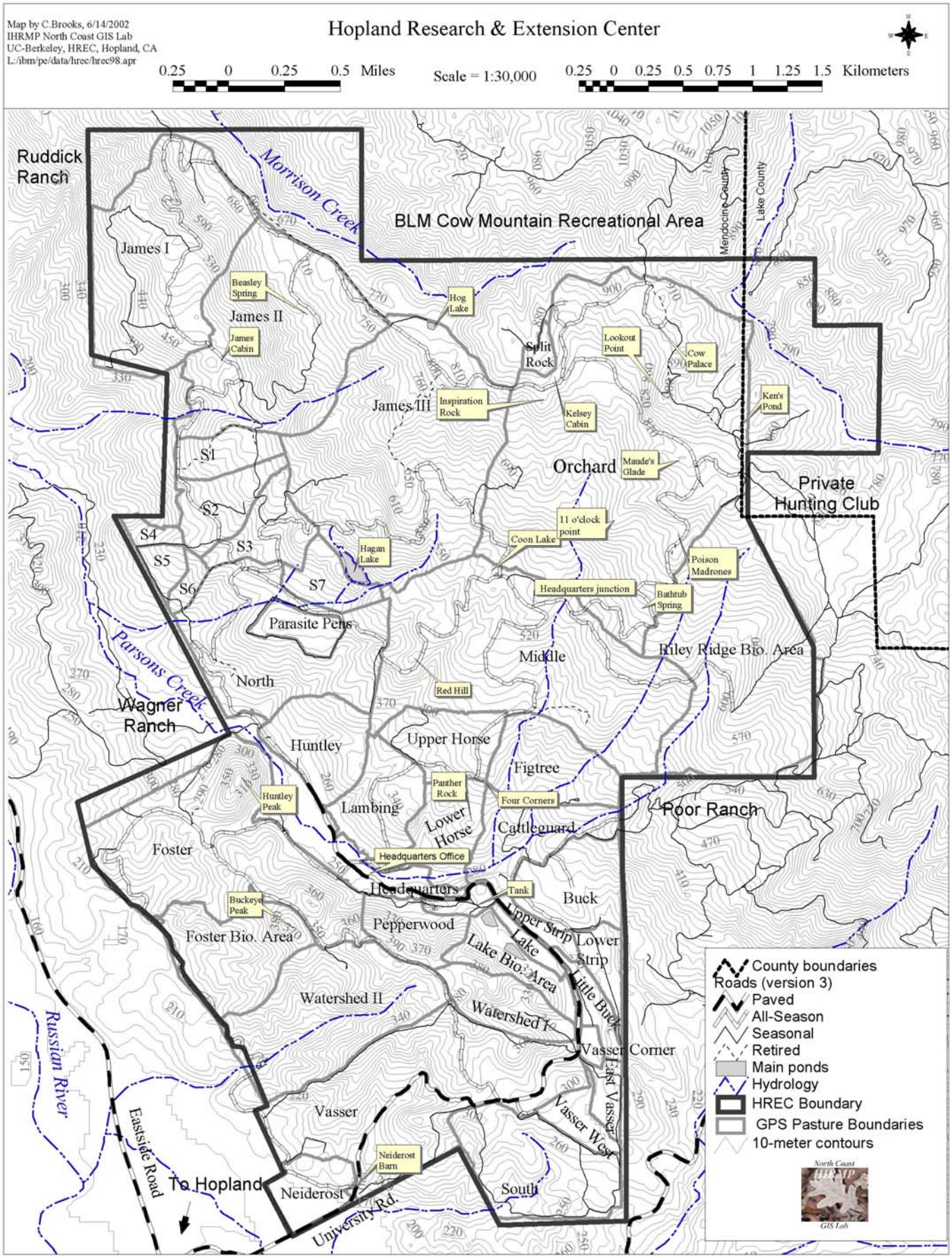
The Center maintains a research flock of 600 to 1,000 breeding ewes. These sheep, together with their lambs and a small flock of rams, graze the majority of the Center's rangelands. Lambing generally occurs between November and February, and shearing takes place in April. Many of the Center's sheep are involved in multiple animal science research projects.

Vegetation conversion and rangeland improvement studies at Hopland over time have resulted in more productive rangelands, some of which have been seeded with varieties of subterranean clover and are fertilized periodically with sulfur and phosphorus. Chaparral vegetation in some locations has been removed by crushing, controlled burning, and other techniques to improve habitat both for livestock and for wildlife. Two small vineyards of winegrapes now occupy approximately 5 acres, providing opportunities for research on new varieties and on vineyard management strategies appropriate to Mendocino County.

Facilities

The main office/laboratory complex houses a small library, a meeting room, and office space for permanent staff and researchers. The all-purpose laboratory is equipped for a variety of standard soil, water, and vegetative analytical tasks and is supervised by a Staff Research Associate. A 950-square-foot greenhouse and a 72-tank lysimeter complement plant science research. Livestock facilities include three sheep barns with working corrals. Warehouses, feed storage structures, and mechanical, welding, and woodshops provide support for Center operations including animal husbandry and the maintenance, construction, and modification of equipment for research purposes.

Visiting researchers, technicians, and students may stay in a modern 22-bed bunkhouse equipped with cooking and laundry facilities. Additionally, 7 permanent residences are maintained for lease by Center staff.


Map by C.Brooks, 6/14/2002
IHRMP North Coast GIS Lab
UC-Berkeley, HREC, Hopland, CA
L:/ibm/pe/data/hrec/hrec98.apr
Hopland Research & Extension Center
0.25 0 0.25 0.5 Miles
Scale = 1:30,000
0.25 0 0.25 0.5 0.75 1 1.25 1.5 Kilometers
Ruddick Ranch
Morrison Creek
BLM Cow Mountain Recreational Area
Mendocino County
Lake County
James I
James II
James III
Beasley Spring
James Cabin
Hog Lake
Split Rock
Lookout Point
Cow Palace
Ken's Pond
Inspiration Rock
Kelsey Cabin
Orchard
Maude's Glade
Private Hunting Club
S1
S2
S3
S4
S5
S6
S7
Hagan Lake
11 o'clock point
Coon Lake
Poison Madrones
Headquarters junction
Bathtub Spring
Parasite Pens
Middle
Riley Ridge Bio. Area
Parsons Creek
North
Red Hill
Wagner Ranch
Huntley
Upper Horse
Figtree
Panther Rock
Four Corners
Huntley Peak
Lambing
Lower Horse
Cattleguard
Poor Ranch
Foster
Headquarters Office
Headquarters
Tank
Buck
Buckeye Peak
Pepperwood
Upper Strip
Lower Strip
Lake
Lake Bio. Area
Little Buck
Foster Bio. Area
Watershed II
Watershed I
Vasser Corner
East Vasser
Vasser West
Vasser
Russian River
Eastside Road
To Hopland
Neiderost Barn
Neiderost
South
University Rd.
County boundaries
Roads (version 3)
Paved
All-Season
Seasonal
Retired
Main ponds
Hydrology
HREC Boundary
GPS Pasture Boundaries
10-meter contours
North Coast IHRMP GIS Lab

Don Holt

ANIMAL SCIENCE

1001. Allo, Andrew A. 1971. **Comparative rates of fermentation in the digestive systems of sheep and deer.** M.S. Thesis, Univ. Calif. Davis. 56 pp.
Abstract: The abundance and widespread presence of cellulose, a major component of plant material, represents a large potential energy source for herbivorous animals. Ruminants are capable of obtaining energy from this fraction of their diet with the aid of microorganisms found in the rumino-reticulum and the caeco-proximal colon, which are involved in the process of fermentation of carbohydrates. This study was undertaken 1) to compare the rates at which the acids are produced in sheep and deer placed on experimental diets; 2) to determine both quantitatively and qualitatively the amounts and proportions of volatile fatty acids (VFA) produced; 3) to determine the caloric equivalent of each of the VFA produced daily; and 4) to compare energy relationships between sheep and deer placed on the same diet and on different diets. Whole rumen contents of sheep and deer contained more VFA than either the solids or fluids alone. Concentrations of rumen VFA in sheep were higher during the day than at night. VFA production in sheep reached a peak 2-3 hours after feed consumption. The pattern of VFA concentrations throughout the gastrointestinal tract is similar in sheep and deer. Incubation of whole rumino-reticulum and caeco-proximal colon with their contents is a reliable technique for determining rates of VFA production in the gastrointestinal system. The rates of fermentation were influenced in part by the quality and quantity of the diets. Estimates on metabolic energy requirements met by fermentation products ranged from 24.9% for penned deer to 49.8% for range deer; 59.4% for sheep fed 100% alfalfa pellets to 95.5% for sheep fed pellets containing 50% grain. Fermentation in the caeco-proximal colon provided 0.7 to 10.2% of the daily metabolic energy requirements.

1002. Anderson, Gary B. 1987. **Embryo transfer and new livestock technology.** Pp. 20-25 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The technique of embryo transfer in sheep is described and evaluated; procedures to induce superovulation, and for collecting and transferring embryos from donors to recipients, are detailed. Possible manipulations of the embryo while *in vitro* are described. Clones have been produced by splitting single embryos and transferring each half to a recipient. Conversely, the combination of cells from two different embryos to form a single composite animal, a "chimera," is also possible. The sheep-goat chimera is useful for study of how the placenta functions to prevent immunological rejection of the fetus. Techniques for *in vitro* fertilization of sheep are under development but, for reasons not yet understood, are more difficult to successfully accomplish from farm animal species than for laboratory animals or for humans.

1003. Baker, Norman F., and James R. Douglas. 1962. **Critical trials with thiabendazole as an anthelmintic in the gastrointestinal tract of cattle and sheep.** Am. J. Vet. Res. 23(97):1219-1223.
Abstract*:* Thiabendazole was found to remove 82% of *Ostertagia* spp. and 98% of *Trichostrongylus* spp. from the abomasum of cattle at a dosage level of 50 mg/kg of body weight. At 100 mg/kg of body weight, 96% of *Ostertagia* spp. and 100% of *Trichostrongylus* spp. were removed. In the small intestine, 50 mg/kg of body weight was only 36% efficient against *Cooperia* spp. At 100 mg/kg of body weight, the drug removed 91% of *Cooperia* spp. At a level of 29 mg/kg of body weight in lambs, anthelmintic efficiency in the abomasum was 85% against *Ostertagia* spp. and 89% against *Trichostrongylus* spp. In the small intestine, however, this level resulted in inadequate anthelmintic activity against *Trichostrongylus* spp. and *Nematodirus* spp.

1004. Bath, Donald L., William C. Weir, and Donald T. Torell. 1956. **The use of the esophageal fistula for the determination of consumption and digestibility of pasture forage by sheep.** J. Anim. Sci. 15(4):1166-1171.
Abstract: A method of obtaining representative samples of forage actually eaten by grazing animals has long been a problem. The many methods previous proposed are time consuming and tedious. The use of the esophageal fistula in grazing animals offers a new approach to this problem. A test conducted to study the change in chemical composition of forage during the process of passing through the mouth and out an esophageal fistula indicated that there was little difference between the sample fed and that collected from the fistula. A technique is described in which esophageal fistulated wethers were used to collect samples of Sudan grass, trefoil, and alfalfa pasture as consumed by grazing sheep and normal wethers equipped with fecal collection harnesses were used to collect feces. Assuming that all sheep are eating the same quality forage and using the lignin-ratio procedure, dry matter consumption, total digestible nutrients, and digestible protein of the pasture forage were calculated. Improvements and possible use of this technique are discussed.

1005. Bell, Monte. 1986. **There's no such thing as normal death loss of lambs.** The Shepherd 31(5):18-20.
Abstract: A system to reduce overall lamb loss in flocks can be very cost effective. Patterns of cause of death can suggest profitable management changes. Lamb death loss studies from the Montana Agricultural Experiment Station, the University of Illinois, and from the U.S. Sheep Station at Dubois, Idaho are reviewed and analyzed. At Dubois, management changes made after studying causes of lamb death reduced mortality from 12.6% to 4.1% in one year. Better record keeping can lead to better diagnosis and management. The article includes a sample Lamb Death Record Form for producers' use.

Jack Kelly Clark

Research sheep on rangeland, April 1996

1006. Bench, Clover J. 1999. **Artificial selection of rams for sexual performance and its effect on the sexual behavior and fecundity of male and female progeny.** M.S. Thesis, Univ. Calif. Davis. 69 pp.
Abstract: The objective of this study was to determine the effect of a single generation of artificial selection of rams for sexual performance on the sexual behavior and fecundity of their male and female progeny. Ninety-two ram lambs born either to sires selected for high or low sexual performance were evaluated for their sexual

behaviors at approximately 8 months of age when individually exposed in 5m × 5m pens to four estrous ewes for 30 minutes in four weekly serving capacity tests. Number of mounts and successful matings (ejaculations) were recorded. Fourteen of the 17 high-performing ram lambs identified were sired by high-performing sires whereas 22 of the 37 low-performing ram lambs were sired by low-performing sires. This result was significant ($P < 0.01$). As a group, sons of high-performing sires exhibited more ejaculations than sons of low-performing sires (mean ± SE = 15.4 ± 12.0 and 10.4 ± 6.2, respectively; $P < 0.02$). Groups did not differ in mating efficiency (ejaculations per total number of mounts). In addition, daughters of high performing rams (N = 79) exhibited their first behavioral estrus approximately 8 days earlier than daughters (N = 61) of low-performance sires (mean ± SE = 274 ± 1.8 and 282 ± 2.4 days, respectively; $P < 0.005$). Ovulation rates for the two groups of ewe lambs did not differ ($P = 0.55$). It was concluded that a significant response to artificial selection for sexual performance in rams can be attained in both male and female offspring in a single generation.

1007. Bench, Clover J., Edward O. Price, Martin R. Dally, and R. E. Borgwardt. 2001. **Artificial selection of rams for sexual performance and its effect on the sexual behavior and fecundity of male and female progeny.** Appl. Anim. Behav. Sci. 72:41-50.
Abstract: The objective of this study was to determine the effect of a single generation of artificial selection of rams for sexual performance on the sexual behavior and fecundity of their male and female progeny. Ninety-two ram lambs born either to sires selected for high or low sexual performance were evaluated for their sexual behaviors at approximately 8 months of age when individually exposed to four estrous ewes for 30 minutes in four weekly serving capacity tests. Number of mounts and successful matings (ejaculations) were recorded. Fourteen of the 17 high-performing ram lambs identified were sired by high-performing sires, whereas 22 of 37 low-performing ram lambs were sired by low-performing sires ($P < 0.01$). Sons of high-performing sires exhibited more ejaculations ($P < 0.04$) and more mounts without ejaculation ($P < 0.02$) than sons of low-performing sires. The two groups of ram lambs did not differ in mating efficiency (ratio of ejaculations to total mounts). Daughters of high performing rams (N = 79) exhibited their first behavioral estrus approximately 8 days earlier than daughters (N = 61) of low-performance sires ($P < 0.005$). Ovulation rates for the two groups of ewe lambs did not differ ($P = 0.55$). It was concluded that there was sufficient genetic variation in the population of sheep studied to obtain a significant response to selection for ram sexual performance in both male and female offspring in a single generation.

1008. Berger, Trish. 1996. **Fertilization in ungulates.** Anim. Reproduction Science 42:351-360.
Abstract: The fertilization process is critical for the preservation of mammalian species. The range in sperm fertilizing potential (the magnitude of genetic and environmental variation present in the population) will influence the assay sensitivity required to detect differences in sperm fertilizing potential to determine the most fertile ejaculates. Interaction with the zone pellucida (ZP) and interaction with the oolemma are two bioassays suggested to assess variation in sperm fertilizing potential. Relatively fertile populations exhibit variation in sperm interaction with the ZP. Multiple sperm receptors for the ZP may exist, potentially with some redundancy in function. Interaction with receptors on the oolemma appears to contribute to the variation in sperm fertilizing potential observed within relatively fertile populations.

1009. Berger, Trish, and Martin R. Dally. 2001. **Is there a sire-dam interaction in sperm fertilizing potential?** Calif. Agric. 55(6):25.
Abstract: This article briefly summarizes an experiment to determine if there is a male-female interaction in the fertilizing potential of sheep sperm. A high level of reproductive efficiency is important to livestock producers, because they must spend a large proportion of their resources on the breeding herd. In a study done at Hopland, Targhee-type ewes were synchronized and then artificially inseminated with a mixture of sperm from 1 of 5 combinations of Merino and Suffolk rams. Ewes that lambed the first year were inseminated in the second year with the same combination of semen, preserved by freezing. The sire of each lamb was determined by the coat color of the lamb's head and legs. Lambing results revealed that 5 of the 10 subgroups varied significantly between years; it was concluded that there is a lack of sire-ewe interaction. This suggests that factors influencing fertilizing potential of sperm are specific to the sperm rather than to the interaction with the female reproductive tract.

1010. Berger, Trish, and Martin Dally. 2001. **Do sire-dam interactions contribute significantly to fertility comparisons in heterospermic insemination trials.** Theriogenology 56:535-543.
Abstract: The percentage of offspring sired after heterospermic insemination of equal numbers of spermatozoa is believed to be a very sensitive measure of relative *in vivo* fertility of the inseminated samples. The objective of these trials was to evaluate whether there was a detectable male-female interaction in the fertilizing ability of spermatozoa. If there was such an interaction, we reasoned that the paternity of offspring from individual females in a heterospermic trial the second year would be similar to the paternity of offspring in the same individual females the first year if the same ejaculates were used. Five groups of ewes were inseminated with different combinations of semen (a single Merino ejaculate from one of five rams randomly paired with five different pools of Suffolk semen) in a heterospermic trial. Those ewes conceiving the first year were inseminated in a second breeding season with the same combination of semen used previously. The percentage of lambs sired by each ejaculate/pool of ejaculates was calculated for all lambs born from all ewes inseminated with each semen combination. These percentages would be the expected ratios of Merino-sired:Suffolk-sired lambs if there is no male-female interaction. Ewes in each group were divided into two subgroups: those conceiving only Merino-sired lambs the first year and those conceiving at least one Suffolk-sired lamb the first year. The ratio of Merino-sired lambs:Suffolk-sired lambs did not differ in either subgroup from those expected if there was no male-female interaction. These results are consistent with the absence of a male-female interaction in relative fertilizing ability of spermatozoa.

1011. Berry, Steven L., Monte Bell, and Aaron Nelson. 1987. **Immunization of ewes for more twins– Fecundin.** Pp. 18-19 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The authors report on trials conducted to evaluate the effect of Fecundin, a commercial product developed in Australia to increase the incidence of twinning in sheep. Discovered by Australian scientists, the product consists of the reproductive hormone androstenedione attached to a large protein (human serum albumin). When injected into ewes, it immunizes the animal against the hormone, resulting in an increased ovulation rate. The product is marketed in Gt. Britain, New Zealand, and Australia. In a trial on 300 commercial crossbred ewes in Glenn County, it resulted in a net increase of 0.4 lambs/ewe. A second, similar trial in Fresno County resulted in treated ewes producing 22% twins as compared to 11% twins in the control group; this difference approached significance. Preliminary work done in Oregon suggests that ewes in excellent condition (body condition score 3.5 - 4) that have a high ovulation rate will benefit little from the treatment.

1012. Berry, Steven L., and John S. Glenn. 1987. **Sheep production cycle.** Pp. 1-4 *in:* Proc. Sheep Breeding School,

Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The authors provide an outline of a year's sheep production cycle, beginning with lambing. Animal health and husbandry considerations are noted for the year's events including marking, shearing, weaning, pre-breeding, ram evaluation, breeding, post-breeding, and pre-lambing. The outline provides a useful starting point for producers to adapt this management calendar for their own particular situation.

1013. Bissell, Harold D., and William C. Weir. 1957. **The digestibilities of interior live oak and chamise by deer and sheep.** J. Anim. Sci. 16(2):476-480.
Abstract: Sheep and deer occupy the same ranges in many places in the coastal chaparral of Northern California, and their diets include the same species at certain seasons. Rumen samples from 139 deer and 68 sheep taken at Hopland and analyzed by Howard Leach of the Dept. of Fish & Game indicate chamise (*Adenostoma fasiculatum*) and interior live oak (*Quercus wislizenii*) are among the most important browse species for both animals. Deer ate these species in all seasons with heaviest use in the spring and summer, and sheep ate them primarily during the late spring and summer. Digestion trials using both animals on the same rations were devised in an attempt to compare efficiency of digestion and obtain a more accurate knowledge of the value of these browse species in planning management of a chaparral area. The protein digestibility of chamise by deer and sheep was superior to live oak but inferior to alfalfa hay. Total digestible nutrients (TDN) is high in alfalfa, slightly lower in chamise, and much lower in live oak. Chamise will supply TDN and some of the protein requirements. Interior live oak has relatively little value as a protein source although it provides a fair amount of TDN. Sheep and deer did not differ significantly in their ability to utilize alfalfa, chamise, or live oak.

A. H. Murphy

Animal Science specialist Don Torell with twin lambs, February 1968

1014. BonDurant, Robert H., Donald T. Torell, L. Layton, and C. Munro. 1980. **Attempted increase in twinning rates via immunization of ewes against androstenedione.** Proc. West. Sect. Am. Soc. Anim. Sci. 31:164-166.
Abstract: European and Australian researchers have reported on the use of induced antihormones, directed primarily against androstenedione, in order to influence ovulation rates in livestock. Here, a vaccine against androstenedione was used in crossbred commercial ewes. The fertility, fecundity, and periestrous endocrinology of these ewes following vaccination is reported. Plasma LH of the immunized group peaked significantly later than in the control group. There was no difference in the rate of twinning between the two groups; neither was there a difference in the infertility rate. The fact that the ovulatory surge of LH in immunized ewes was significantly delayed but that the onset of estrus was not, suggests the possibility that ova may be "aging" even before ovulation, thus reducing their fertility. Several alternative hypotheses are suggested to explain the lack of an observed increase in reproductive performance.

1015. Bradford, G. Eric, William C. Weir, and Donald T. Torell. 1960. **Growth rate, carcass grades and net returns of Suffolk and Southdown-sired lambs under range conditions.** J. Anim. Sci. 19(2):493-501.
Abstract: A three-year experiment was conducted to compare the performance of Suffolk- and Southdown-sired lambs in an area characterized by a relatively short period of good feed supply. One hundred whiteface ewes of mixed breeding were allotted each year to three or to four rams of each breed. The results indicated that the lighter weights of the Southdown-sired lambs were not compensated for by their slightly higher carcass grades and percentage survival to weaning, and that the lambs sired by rams of the larger breed returned approximately 16% more lamb income per ewe.

1016. Bradford, G. Eric, William C. Weir, Donald T. Torell, and G. M. Spurlock. 1960. **Suffolk and Southdown rams as sires of market lambs compared in long-term study.** Calif. Agric. 14(8):4-5.
Abstract: A three-year experiment at Hopland compared lambs sired by rams of a larger breed with those sired by rams of a smaller, earlier-maturing breed. The lambs compared were sired by Suffolk and Southdown rams, and were out of range ewes. Suffolk rams are used for crossing for market lamb production in many parts of the state, including the North Coast area. Southdowns are not extensively used in commercial operations but are the most common breed in flat lamb classes at livestock shows because of their compact conformation and ability to pun on finish at light weights. Since fat lambs bring a substantially higher price than lambs which are not ready for slaughter at weaning, it was of interest to determine the extent to which finishing ability of lamb of the smaller breed would compensate for their lighter weights. This problem is of particular importance to areas such as the North Coast area since, in an average year, lambs of the larger breeds do not reach market finish by the time the feed dries and they must be weaned. Approximately the same proportion of ewes in both groups lambed, but ewes bred to Suffolks raised fewer lambs to weaning because of greater lamb mortality. Southdown lambs also showed an advantage in percentage of fat lambs– 30% against the 24% of the Suffolks– but this difference was not so large as expected. Suffolk-sired lambs weighted 12 lbs more than the Southdowns by four months of age, and since the difference in carcass grade in favor of the Southdowns was not large enough to make much difference in price, the Suffolks consistently returned more money per lamb. Income per ewe in the Southdown-sired group was relatively better than income per lamb because of the higher weaning percentage, but was still $1.77 less per head than for ewes bread to Suffolks. The results indicate that under the marketing conditions existing in California, and probably over most of the country, the importance of weight in determining returns is such that only small weight differences are necessary to compensate for rather wide differences in conformation and earliness of maturity.

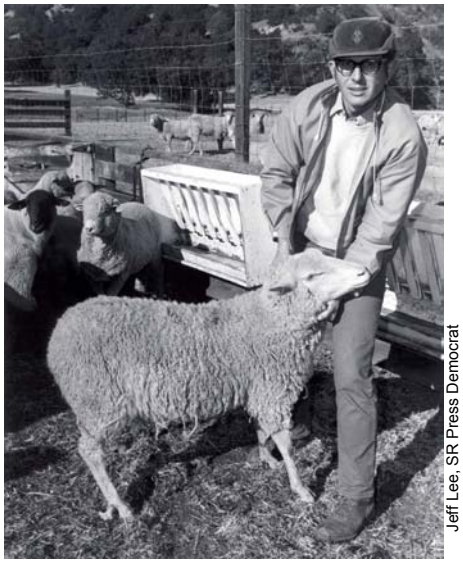
1017. Bradford, G. Eric, William C. Weir, and Donald T. Torell. 1961. **The effect of environment from weaning to first breeding on lifetime production of ewes.** J. Anim. Sci. 20(2):281-287.
Abstract: The effect of plane of nutrition during first year of life on

lifetime lamb and wool production of ewes was studied. Fifty ewes representing two breed groups were reared on unsupplemented range from 6 to 16 months of age, while 50 comparable ewes grazed on irrigated pasture during the summer and were then fed hay and grain in drylot during the winter. All ewes were carried under range conditions after 16 months of age. Range-reared ewes were 25% lighter as yearlings and remained significantly lighter through three years in a common environment. They produced substantially less wool as yearlings and slightly less thereafter. First-year treatment did not significantly affect lifetime lamb production, although number of lambs produced and therefore total weight of lamb favored the range-reared ewes. Rambouillet-Merino ewes were lighter in weight and narrower chested than Corriedale-sired ewes, but produced more wool and lambs that were at least as heavy. The results indicate that the problem of optimum ewe size in relation to the environment needs further investigation.

1018. Bradford, G. Eric, Donald T. Torell, G. M. Spurlock, and William C. Weir. 1963. **Performance and variability of offspring of crossbred and purebred rams.** J. Anim. Sci. 22(3):617-623.
Abstract: Hampshire, Suffolk, and Hampshire-Suffolk crossbred rams from comparable parents were tested in topcross tests on commercial ewes in the Hopland Field Station flock and in four cooperator flocks. A total of 12 rams and approximately 270 ewes for each of the three groups were included in these tests. No consistent differences in lambing percent or lambing date were found among the three sire groups. No undue lambing difficulty was noted in any case. Crossbred-sired lambs showed an advantage of about 4% in lamb survival over the two-parent breed groups, which were similar when averaged over all trials. Crossbred sired lambs were intermediate between the two parent breed groups in weights at birth and 120 days, though they approached the heavier breed mean in the latter. Crossbred-sired lambs had higher live grades than the Hampshire and Suffolk average at Hopland but not in the other flocks. Carcass data supported the conclusion that crossbred-sired lambs carried more finish at weaning in the Hopland flock. These results were discussed in terms of desirable characteristics of both breeds being combined in the progeny of the crossbreds. Variability, estimated within sex and type of birth subclass, and pooled over all comparisons, was non-significantly lower for crossbred-sired progeny than for purebred-sired progeny, for all trials. It is concluded that the use of crossbred rams will result in mean performance at least equal to and variability no greater than that obtained by using purebred rams. There was an indication that survival may be superior for crossbred-sired progeny, and that finishing ability may be improved in some cases, the latter probably attributable to the two particular breeds used in this study.

1019. Bradford, G. Eric, and G. M. Spurlock. 1964. **Effects of castrating lambs on growth and body composition.** Anim. Production 6(3):291-299.
Abstract: Effects of castration on growth, wool production, carcass characteristics, and meat quality in sheep were investigated. The experiment included two flocks (similar in their effect on pre-weaning performance, but representing high and low planes of nutrition after weaning), two years, and two slaughter ages. Rams weigh approximately 5% more than wethers at weaning, and 15% to 23% more as yearlings on the low and high planes of nutrition, respectively. Differences in favor of rams in terms of skeletal and muscle size and wool production were also greater on the higher plane of nutrition. Carcass weight was approximately 4%, 8%, and 19% higher for rams among lambs, low plane, and high plane yearlings, respectively. Proportion of carcass weight in the forequarters was 0.5%, 1.1%, and 2.3% higher for rams in these groups. Rams had less kidney fat and the same percentage of the carcass weight in the loin and trimmed leg as wethers in all groups. Carcass grade and eating quality as evaluated by a taste panel did not differ between ram and wether lambs. Among the lighter yearling group, meat from the loin of ram carcasses was less tender. Quality was appreciably lower for rams in the heavier yearling group. Meat from ram carcasses had 1 to 2% higher cooking loss than that that from wethers.

1020. Bradford, G. Eric. 1972. **Genetic control of litter size in sheep.** J. Reprod. Fertil., Suppl. 15 (1972):23-41.
Abstract: Evidence on genetic variation in litter size in sheep, defined as the total number of lambs born per parturition, is reviewed. Breed means ranging from a little above 1.0 to above 3.0 have been reported; differences between breeds under uniform environmental conditions certainly exceed a two-fold range. The trait appears to act approximately additively in crosses between breeds differing widely in litter size, although heterosis has been found in some studies. Within breeds, heritability of litter size is on average quite low, probably not higher than 15%; nevertheless, appreciable selection response has been reported in several cases. Heritability and repeatability, as well as the mean for other traits, may be affected by environmental variables such as age and level of nutrition, and may also differ between breeds. It is concluded, primarily from a consideration of results of egg transfer, that ovulation rate is the main factor limiting litter size, at least in breeds in which it is low. Breeds differ with respect to litter size following transfer of a standard number of eggs, but the differences are, on average, much less than those in ovulation rate. Genotype of the embryo appears to have little effect on litter size. It is therefore suggested that attempts to improve genetic potential for litter size should be directed towards increasing ovulation rate, although it also appears that this may increase variability in litter size.


Jeff Lee, SR Press Democrat

Assistant shepherd Richard Rainoldi holding yearling ram with Finnish Landrace breeding, October 1971

1021. Bradford, G. Eric, and Donald T. Torell. 1973. **Performance of Finnish Landrace crossbred ewes (Abstract).** J. Anim. Sci. 37: 230.
Abstract: Five Finnish Landrace rams have been used in a breeding program to measure the performance of ewes carrying 50% or 25% of their inheritance from this breed. At Davis, under drylot conditions on a high plane of nutrition, Finnish Landrace × Targhee ewes born in two years and lambed at one and two years of age were 38 to 48% superior to contemporary Targhees in numbers of lambs born, and 21-39% superior in numbers of lambs weaned. The two groups were very similar in proportion of ewes lambing. Nine groups of 2-year-old ewes born and raised in the Hopland Field

Station flock, representing a much lower plane of nutrition, were all bred to Suffolk rams and lambed for the first time at two years of age in 1973. Performance of these, given as number of ewes bred-number lambed-mean litter size per ewe lambing, was as follows: Targhee (control, C, and weight selected, W) and Corriedale × Targhee (combined because of very similar reproductive performance) 58-52-1.15; Targhee (multiple birth selected, T) 18-16-1.38; Finnish Landrace (F) × Targhee 30-30-1.90; FW × Targhee 38-37-1.30; FT × Targhee 29-28-1.39; Suffolk (S) × Targhee 40-35-1.46; FS × Targhee 28-28-1.68. These results indicate 1) the superiority of half Finnish Landrace ewes is actually greater in a poorer environment, 2) one-fourth Finnish Landrace– three-fourths Targhee ewes are closer to Targhees than to the F_1 ewes in litter size, suggesting heterosis in F_1 performance, 3) superior conception rate in all ewes carrying some Finnish Landrace breeding, 4) very good performance from Finn-Suffolk sired ewes.

Replacement ewes in irrigated Niderost Pasture

1022. Bradford, G. Eric. 1974. **Increasing lambing percentage.** Calif. Livestock News 29(1):12-15.
Abstract: A high lambing percentage at weaning depends on: 1) ewes with a high genetic potential for multiple births, 2) management of ewes and rams at breeding time to permit expressions of that potential, and 3) management at and after lambing for high lamb survival. A high genetic potential may be introduced into a flock lacking it by crossbreeding with a prolific breed, or by selecting for multiple births in choosing replacement ewes and, more importantly, in choosing rams to use as sires of replacement ewes. Crossing with the Finnish Landrace breed will produce the largest increase since this is the most prolific breed available. Mature crossbred ewes sired by Finnish Landrace rams out of Western whiteface ewes will give birth to 2.2 - 2.5 lambs per ewe lambing under good feed conditions, and probably about 2.0 even under rather poor range conditions. Other advantages of such ewes include high conception rates, early puberty, and high lamb livability at birth; potential disadvantages include poorer carcass conformation, light fleeces, and a shorter breeding season at least when compared to ewes of predominantly fine wool breeding. Present evidence indicates that some percentage of inheritance from this breed, probably in the range of 25% to not more than 50%, will increase flock productivity in many situations. A good within-flock selection program may be expected to increase lambing percentage born by 1.5 - 2.0% per year; raising all or most of the additional lambs produced by this method (or by crossing) will usually require more intensive management at lambing. A stratified selection scheme for increasing multiple births in large flocks, in which records are required on only a small proportion of the animals in the flock, is outlined. Maintaining ewes in good condition throughout the year or, where this in not economical, providing a high plant of nutrition for one cycle prior to breeding, is necessary for expression of the ewes' genetic potential for multiple births. On the other hand, nutrition during early pregnancy has much less effect on lambing percentage. High ram fertility is important not only for high conception rates, but also for maximum potential incidence of multiple births.

1023. Bradford, G. Eric. 1977. **Replacement ewes for California sheep flocks.** Mimeograph, presented at California Livestock Symposium, Fresno, CA, 6 pp.
Abstract: With approximately 11 million ewes in the U.S. the sheep industry needs between 2.2 and 2.7 million replacements annually, 160,000 to 200,000 of these in California. Cost of replacement ewes represents 15 to 20% of the gross cost of lamb production. While growth rate and carcass quality of the lambs is affected by the quality of rams used, the ewe contributes equally to these traits, and more importantly, determines the potential for 1) time of year the sheep producer may choose to lamb, 2) number of lambs born, 3) milk supply for the lambs, and 4) amount and quality of wool produced. Thus the production potential of the flock depends very largely on the genetic potential of the ewes in it. At this time, it may be more economical for California producers to buy than to raise replacement ewes. Where this is so, attention to quality control, possibly through a contractual arrangement with producers in another state to produce ewes of a specified breed or cross, should be considered if possible. In general, the decreasing supply of quality replacement ewes from out of state, along with availability of new breeds excelling in particular traits and of knowledge of how to use them, argue for more breeding of replacements in California. Quality control of replacement ewes has too much to offer to the California sheep industry to leave it to others or to chance. Methods of improving out-of-season breeding characteristics are not as yet well developed, but new breed combinations, and selection within present populations, should both be useful tools in achieving this objective. This area will probably receive major attention from sheep researchers in the next few years. By varying the breed combination, one can set the mean genetic potential for litter size of a flock at any reasonable level desired, from current levels of 1.1 to 1.5, up to levels as high as 2.5 or perhaps higher. *Optimum* level will depend upon nutrition and management. For many current management conditions, it appears that infusion of 25% Finnish Landrace into conventional whiteface ewe flocks may be about right, increasing lambing percentages at birth and weaning by 20-30% while maintaining a well-adapted ewe. The main step needed now to apply available tools for sheep improvement is for breeders to organize to produce the necessary rams and ewes. This can be done by individual large operators, or by groups of producers. In New Zealand, several group breeding schemes involving a total of over 500,000 ewes have been developed for sheep improvement. While the California sheep industry differs from that in New Zealand in several important respects, the idea of a collaborative effort to improve the state's sheep is one that we should be able to adapt effectively for improvement of the productivity and profitability of California sheep.

1024. Bradford, G. Eric, Donald T. Torell, L. L. Lasslo, and R. Neira. 1981. **Selection for growth and reproduction in Targhee sheep.** Proc. 1981 Sheep and Wool Days. Special Rep. 613, Oregon State Univ. Agric. Exp. Stn., Corvallis, OR, pp. 42-55.
Abstract: Long term selection for high 120-day weights in Targhee sheep was carried out in two locations, one representing a high plane of nutrition typical of that often found in purebred flocks, the other a rather harsh range environment. A second selected group, mated continuously to rams "imported" from the better environment, was maintained in the range flock. Response to selection was higher in the better environment, because animals with high growth potential express it to a greater degree under better feed conditions. Selection under good conditions was at least as effective in improving growth rate of sheep raised under range conditions as was selection under

range conditions. Weight of lamb weaned per ewe mated increased, but less so than individual lamb weaning weight because of decrease in lamb survival in all three lines selected for high weaning weight. Mature weight has increased significantly as a result of selection for weaning weight. Correlated changes in other traits also are being studied. A high multiple birth strain was initiated with the best approximately 20% of a group of several hundred ewes on lifetime number of lambs born. The initial selection produced a line with an average of approximately 15 more lambs per 100 ewes than an unselected control. This difference has been maintained but not increased by continued selection. Weight of lamb weaned by multiple birth line ewes is higher than for the control line and in fact slightly higher than in the weight-selected lines, without an accompanying increase in mature ewe weight. Thus, efficiency in terms of lamb weight weaned per unit of feed input to the flock probably is highest in the multiple birth line.

1025. Bradford, G. Eric, and Donald T. Torell. 1982. **Correlated responses to selection for 120-day weight in Targhee sheep.** J. Anim. Sci. 55(Suppl. 1):153-154.
Abstract: Selection for 120-day weight in Targhee sheep was carried out under irrigated pasture/drylot conditions at Davis (line DW) and under range condition as Hopland (HW). Unselected control lines were maintained in both environments (DC, HC1 and HC2), and a fourth line (DH) was propagated at Hopland by mating selected DW rams to Hopland ewes. Regression estimates of the increase in 120-day weight in lines DW (15 years) and HW and DH (20 years) were 20, 10, and 15% of the appropriate control line mean. Mature ewe weight increased to about 14% above the control mean in each of the three selected lines. Birth weight increased significantly in all three selected lines, but significantly less in DH than in the other two. Proportion of ewes lambing decreased in the selected lines relative to the controls, with DH showing an average decrease of over 1%/year ($P < .01$). Difference in litter size between line within locations were not significant in any case, although HW tended to increase. Lamb survival decreased in all 3 selected lines, significantly so in lines DW and DH. As a result of the decreases in fertility and lamb survival, none of the selected lines produced significantly more total lamb weight per ewe than the controls, in spite of the direct response to selection. Per unit of ewe metabolic both weight, DW, HW, and DH all produced less lamb weight than the controls, with the decline in DH significant. The results indicate that while selection for growth rate to weaning results in heavier lambs, the practice may have a negative effect on net flock productivity, at least for within strain matings.

1026. Bradford, G. Eric. 1985. **Ch. 1. Selection for litter size.** Pp. 3-18 *in:* R. B. Land and D. W. Robinson (eds.), Genetics of Reproduction in Sheep. Butterworth's, London.
Abstract: Litter size or number of lambs per parturition is an important component of productivity in sheep, contributing much more to difference in total weight of lamb weaned per ewe than does growth rate of individual lambs. However, for the first few decades of the modern era of genetics, animal breeders accepted the view, based on heritability estimates, that genetic variation in twinning rate or litter size was too low to justify trying to change it by genetic means, except perhaps to utilize the one-time increase from crossing breeds. Research conducted by others during the 1960s changed that perception. It is now generally accepted that genetic potential for mean litter size in sheep can be set at any desired level from 1 to about 3. Research interest is therefore shifting to determining what levels of prolificacy are optimum for different production environments, what is the most efficient means of achieving and maintaining those levels, and how to minimize variation around the mean. This chapter considers goals for litter size and the potential role of selection in achieving those goals. Results from Hopland experiments selecting for prolificacy are included in this review.

1027. Bradford, G. Eric, and H. H. Meyer. 1986. **Economic evaluation of breeding objectives for sheep and goats: practical considerations and examples.** Pp. 479-492 *in:* Proc. 3rd World Congr. on Genetics Appl. to Livestock Production, Vol. IX, Lincoln, NE.
Abstract: Examples of breeding objectives for sheep industries with well developed breeding programs such as in Australia and New Zealand are reviewed briefly. For industries lacking adequate information on genetic and economic parameters to quantify objectives precisely, some general guidelines for choice of objectives are outlined, and it is suggested that considerable genetic progress can be made in such industries by use of sound objectives in choice of breeds, breed combinations, or base populations for multiplication. Objectives which it is suggested merit increased attention include: 1) defining optimum litter size and mature size, 2) improving lamb viability, 3) improving longevity and disease resistance, 4) reducing labor requirements (improving easy care traits), 5) improving feed conversion, 6) reducing seasonality of breeding; and 7) reducing variability in litter size. Breeding objectives for goats are discussed briefly.


Jeff Lee, SR Press Democrat

Barbados ram in "Parasite Pens" facility, North Pasture, October 1971

1028. Bradford, G. Eric, and J. F. Quirke. 1986. **Ovulation rate and litter size of Barbados, Targhee and crossbred ewes.** J. Anim. Sci. 62:905-909.
Abstract: Ovulation rate was measured in Barbados Blackbelly (United States strain; B), Targhee (T), Barbados × Targhee (B × T), and Barbados × Dorset-Targhee (B × DT) ewes at first and second estrus following synchronization of cycles early in the breeding season. Body weight at sponge removal differed ($P < .001$) between B (30.9 kg) and T ewes (54.9 kg) and was intermediate for B × T (44.9 kg) and B × DT (43.5 kg) ewes. Ovulation rate was higher ($P < .01$) at first and second estrus for B (1.86, 2.04), B × T (1.93, 2.04), and B × DT (1.72, 1.80) than for T (1.29, 1.40) ewes. Regressions of ovulation rate on body weight within the breed groups did not differ significantly from each other and the average was significant (b=.049 ± .014 CL/kg at first estrus and b = .046 ± .011 CL/kg at second estrus, where CL = number of corpora lutea), but differences between the groups in body weight did not explain the differences in ovulation rate. Litter size for B, B × T, B × DT, and T groups was 1.71, 1.84, 1.84, and 1.28 respectively. The B × T ewes were superior to the average of the B and T ewes for ovulation rate ($P < .05$) and litter size ($P < .01$); there was no direct estimate of embryo survival, but the results indirectly indicate superiority of the crossbreds for this component also. The B, B × T, and B × DT ewes were all exceptionally uniform in ovulation rate and litter size; 81% and 69% of the CL counts for B and B crossbred ewes, respectively were two, and 68% and 79% of the litters produced by B and B crossbred ewes, respectively, were twins.

1029. Bradford, G. Eric, J. F. Quirke, and T. R. Famula. 1986. **Fertility, embryo survival and litter size in lines of Targhee sheep selected for weaning weight or litter size.** J. Anim. Sci. 62:895-904.
Abstract: Conception rate, prenatal survival, and litter size were recorded for 444 ewes of two age groups from five lines of grade Targhee sheep: two unselected control lines, HC1 and DC(C); two lines selected for 20 years for increased 120-day weight, HW and DH(W); and a line selected for 18 years for increased multiple births, T. Line T was equal or superior to the control lines in conception rate, prenatal survival, and litter size in both age groups, although most of the differences were not significant. The W selected lines were inferior to the C and T lines in fertility and tended to be lower in prenatal survival, among mature ewes, resulting in a significantly lower number of lambs born per corpus luteum in the W lines than in the other two groups. Among yearlings, C ewes were non-significantly lower in fertility than T and W ewes, while W ewes were significantly lower than C and T ewes in prenatal survival. The T line ewes had higher overall reproductive performance than either of the other two groups. Ewes with ovulations had a significantly higher conception rate than ewes with single ovulations. Gestation period was exceptionally uniform with a coefficient of variation of 1.3% and little difference due either to line or litter size. It was concluded that selection for multiple births improved overall reproductive performance, whereas selection for increased growth rate had an adverse effect on several components of reproduction, leading to a net decline in fitness.

1030. Bradford, G. Eric, and Dana B. Van Liew. 1987. **Selection for genetic improvement and eliminating recessive defects.** Pp. 43-48 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Practical considerations in improving sheep productivity through genetics are summarized and discussed. New technologies such as artificial insemination and embryo transfer can be utilized to obtain more offspring from individual rams and ewes; however, this will improve the productivity of sheep flocks only if the animals multiplied are genetically superior. For this discussion, genetic superiority is defined as being more productive; that is, producing more meat and wool and thus more income per unit of input. Factors affecting productivity are listed. The heritability of various traits in sire breeds and dam (ewe) breeds is discussed. The deleterious effects of defective genes, for example Spider Syndrome in lambs, are discussed along with method for eliminating such genes from the flock.

1031. Bradford, G. Eric, and Y. M. Berger. 1988. **Breeding strategies for small ruminants in arid and semi-arid areas.** Pp. 95-109 *in:* E. F. Thomson and F. S. Thomson (eds.), Increasing Small Ruminant Productivity in Semi-arid Areas. ICARDA, Aleppo, Syria.
Abstract: Sheep and goats that have evolved in arid or semi-arid environments are usually well adapted to their environment. The productivity of these animals is low compared to performance of these species in more favorable environments, but their ability to survive and reproduce in bad years as well as good is remarkable. With increasing human population, an urgent goal is to increase the offtake of small ruminant products i.e., meat, fiber, milk, and skins, without degrading the grazing resource. Crossing locally adapted breeds with breeds selected for higher performance can upset this balance, leading to a loss of adaptation which may impact unfavorably on the lives of many people. Even selection for performance within the adapted breeds may result in a loss of adaptation, though less so than from crossing with exotic breeds. Genetic improvement programs for small ruminants in arid and semi-arid environments should be based on locally adapted breeds. Adaptability, as indicated by viability, fertility, and regularity of reproduction, is usually lower for exotic, improved breeds and often for the crossbreds produced by mating these to local breeds. The possibilities for genetic improvement increase as the level of feeding and management increase. Improvements in productivity of 20-50% are feasible by improving genetic potential. Return on investment in breeding programs is often very favorable, but substantial time is required to achieve goals. A sound breed or crossbreeding evaluation with small ruminants will require 6-10 years and a similar period will often be required to establish a significant response to selection, although effective screening of a large population can establish a significant and visible difference between a nucleus flock and the base population in one generation. The great advantages of selection are that the effects are cumulative over time and relatively permanent. Selection within local stocks has the added advantages of utilizing animals familiar to producers and producing products known and accepted in local markets. The conclusion that importation of exotic breeds may not be the best means of effecting genetic improvement in difficult environments is not new. We still believe this to be generally true, based on physiological aspects of adaptability and disease susceptibility. Unfortunately, this has very frequently been overlooked during the past four decades, and while there have been a few successes, there have been more failures from importations. We recommend that importation of improved breeds should be undertaken only after very carefully evaluating the performance of local breeds under the nutritional and management conditions which would be provided for the imported animals and their crosses. Also, imported breeds should be released only after they or their crosses have been shown to be superior in lifetime performance to local animals under feasible management conditions.

Guy E. Connolly

Sheep being moved through headquarters area to Main Barn, March 1975

1032. Bradford, G. Eric, Martin R. Dally, and H. Sakul. 1992. **The Hopland long term selection project.** Pp. 74-77 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: A selection experiment was designed in grade Targhee sheep to investigate the direct and correlated effects of selection for 120-day weight, and to determine the extent to which improvement through selection under feedlot conditions was expressed under range conditions. Ewes were randomly allocated to weight-selected (DW) and control (DC) lines at Davis and at Hopland (HW, and HC1 and HC2). A separate selection line (DH), mated to rams selected at Davis and subsequently transferred to Hopland, was also maintained at Hopland. Selection started in 1961. In 1963, a multiple birth selected line (HT) was formed at Hopland using older ewes from all lines and additional Hopland flock ewes. Selection continued to date in both weight-selected and multiple birth-selected lines. Response to selection for 120-day weight fluctuated among years. Improve-

ment achieved in the feedlot conditions (Davis) was much more than under range conditions (Hopland). Direct cumulative responses to selection for the first 20 years were 15.8, 7.4 and 10.4 lbs for the DW, HW and DH lines, respectively. It was concluded that genetic potential for early growth rate appears to be expressed more fully under better feed conditions. Also, selection for 120-day weight caused a correlated increase in birth weight and mature weight. While litter size did not change, fertility and lamb survival declined in selection lines. Selection for multiple births resulted in only a little response following an increase of 0.16 lambs per ewe lambing from the initial screening.

1033. Bradford, G. Eric, Martin R. Dally, H. Sakul, R. Kott, C. J. Lupton, and G. D. Snowder. 1993. **Evaluation of Merino and U.S. genotypes for wool and lamb production.** Pp. 8-9 *in:* Proc. Ann. Mtng., West. Coord. Comm. 39**.**
Abstract: Fine wool (FM) and strongwool Merino (SW) cross ewes produced 32% and 46% more clean wool than Targhee ewes at one year of age and showed an even greater advantage in grease weight at 2 years of age than at 1. Group ranking for fleece weight and staple length are identical for 1992 and 1993, confirming the high repeatability of these traits. Mean fleece rot scores were low in all groups both years; since 1992-93 was an exceptionally heavy rainfall season (43 in.), this suggests that fleece rot is not a serious problem for any of these genotypes. However, Targhees weaned 46% and 20% more lamb per ewe in the flock at lambing than FM and SM groups, respectively. No firm conclusions should be drawn from one year's data; however, it appears rather unlikely that the Merino crosses, at least the finewool crosses, will be competitive with U.S. breeds in total lamb and wool production.

1034. Bradford, G. Eric, H. Sakul, R. Neira, T. R. Famula, Martin R. Dally, and C. M. Finley. 1994. **Reproduction in sheep selected for weaning weight or litter size in a range environment.** Pp. 95-98 *in:* Proc. 5th World Congr. on Genetics Appl. to Livest. Prod., Vol. 18, Guelph, Canada.
Abstract: Litter size, fertility, lamb survival, and 120-day weight of lamb per ewe lambing are reported for 4 lines of grade Targhee sheep maintained for over 30 years in a range environment. Two lines were selected for 120-day individual weight (HW, DH), and one for multiple births (HT); HC was an unselected control. Litter size was increased by about .2 from initial screening of ewes into line HT, but did not increase subsequently in spite of continued selection. Litter size increased significantly in line HW, selected continuously in the range environment, while fertility and lamb livability declined slightly. Rams in line DH were imported from a more favorable environment for 17 years, and during that period ewe fertility and lamb livability declined significantly. With selection in this line in the range environment during the second phase, there was significant improvement in these traits. Total 120-day lamb weight per ewe increased modestly in all 3 selected lines. Collectively, the results suggest that selection in the environment of use is preferable to importation from an environment where heritability is higher, but that the rate of improvement in growth or prolificacy will be slow in an environment with a low plane of nutrition.

1035. Bradford, G. Eric, H. Sakul, and Martin R. Dally. 1999. **Selection for weaning weight or litter size in range sheep. II. Correlated responses and effect on productivity.** Sheep and Goat Res. J. 15(3):138-146.
Abstract: Mating weights, ewe fertility, lamb survival, and total 120-day weight of lamb per ewe lambing are reported for an unselected control line (HC) and for lines selected for either adjusted 120-day lamb weight (HW and DH) or littler size (HT). Lines HW and DH achieved mean ewe mating weights about 8 kg above HC, for a greater absolute increase than the approximately 5 kg direct response in 120-day lamb weight. HT increased little in ewe weight. Fertility was consistently highest in HT, while HW and DH were slightly below HC. Lamb survival was consistently highest in HC, followed by HT, HW, and DH. For both fertility and lamb survival, DH, in which rams were selected in a different environment for the first half of the experiment, was consistently lowest. Total 120-day weight of lamb per ewe lambing was highest in HW, as a result of both direct response and a correlated increase in litter size, followed by HT and DH. Considering all traits, it was estimated that lines HW and HT weaned 11 to 12% more lamb per unit ewe metabolic weight than HC. This is an economically significant increase, although relatively small for more than 30 years of selection. The results indicate that response to selection for performance traits is slow in a nutritionally limiting environment, but that useful improvement can be made. The results (for weaning weight) also suggest that selection under range conditions is more effective in improving performance in that environment than selecting in an environment where heritability is higher and then transferring the improved stock.


Barbara J. Wright
Ewe with three lambs, Spring 1994

1036. Briggs, Paul E. 1992. **Evaluating wool on the live animal.** Pp. 84-88 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Guidelines for evaluating and analyzing fleeces on the live sheep are given. Such techniques are useful when selecting replacement animals to be purchased, as well as when culling animals from your flock. The discussion includes such factors as fiber diameter or grade, uniformity, staple length, character, yield, density, belly wool, and kemp.

1037. Brooks, Dale L., A. T. Mariassy, R. Ruppanner, and D. Behymer. 1984. ***C. burnetii* placentitis in sheep: weak lamb and neonatal losses.** *In:* IIIrd Int. Symp. on Rickettsial Diseases, Slovak Acad. of Sciences, Czechoslovak Soc. for Microbiology, Institute of Virology, Bratislava, Czechoslovakia. Sept. 10-14.
Abstract: In the western U.S.A., 24% of the sheep have seroantibodies to *Coxiella burnetii*. The antibody prevalence ranged from 0% in an isolated commercial flock to 78% in a more closely confined research flock. *C. burnetii* is a cause of placentitis in sheep. Infected ewes are usually asymptomatic. This rickettsial organism is readily aerosolized into the environment at lambing from placental tissues and birth fluids. The placental tissues may appear normal to minimal focal placentitis progressing to severe necrotizing changes. This placental pathology progressively decreases the diffusion between the maternal and fetal circulation. Depending on the extent of placentitis, a few lambs from these infected ewes abort in late term pregnancy, are stillborn, or are more likely to be apparently normal at birth. Careful examination of these newborn lambs will show an incidence of smaller and less active animals than those born from ewes with a non-infected placenta. These weaker lambs have an increased susceptibility to the more commonly diagnosed diseases

and causes of the downer syndromes of newborns. Recognition of *C. burnetii* by serology is difficult because both positive and negative ewes can be infected. Vaccines have the potential to reduce the incidence of shedders. Control of placentitis and resultant weak newborn may help to reduce the overall birth to weaning losses of 10% to 30% of lamb crops.

1038. Brooks, Dale L., A. T. Mariassy, and Darrell E. Behymer. 1985. **Q fever in sheep: recent findings on pathological and preventive aspects of the disease.** *In:* Proc. Workshop on Diseases Caused by Leukocytic Rickettsiae of Man and Animals, Univ. Illinois, Champaign, IL.
Abstract: The western U.S. has a 10-30% neonatal lamb mortality. Q fever should be included in the differential diagnoses of lamb losses. Twenty-four percent of ewes are *Coxiella burnetii* seropositive and are usually asymptomatic. Placental tissues of infected ewes may appear normal or have focal placentitis progressing to severe necrotic changes. Depending on the severity of placentitis and resultant loss of circulation, a few abort in late term, are stillborn, or most often, have full-term lambs. Closer examination will show some to be smaller and less active than those born from ewes with non-infected placenta. Ultrastructural studies show compartmentalization of *C. burnetii* in the phagosomes and vacuoles of trophoblasts with little to no inflammatory response. In more severe infections, parasitized cells rupture releasing free organisms into the amniotic fluid and placental exudates. Both seroantibody negative and positive ewes may shed viable organisms. These free forms stimulate a humoral antibody response, but in cell-bound forms the immune system is not confronted. At parturition ewes remain seroantibody negative but shed cell-bound forms into the environment from the autolysing afterbirth. The use of a formalin inactivated whole cell vaccine and a chloroform methanol residue vaccine administered with incomplete Fruends' adjuvant initiated a high humoral antibody response by MA and ELISA tests and a good cellular antibody measured by intradermal skin test response which have remained for over 2 years. Vaccinated challenged ewes had healthier lambs and did not shed rickettsiae in colostral milk, with reduced shedding in the placenta and amniotic fluid as determined by seroconversion on inoculated mice after 21-30 days. Further Q fever vaccine studies are needed to determine enhancements of cellular immunity to prevent intracellular propagation of *C. burnetii* in pregnant ewes.

1039. Brooks, Dale L., R. W. Ermel, Charles E. Franti, R. Ruppanner, Darrell E. Behymer, C. Williams, and J. C. Stephenson. 1986. **Q fever vaccination of sheep: challenge of immunity in ewes.** Am. J. Vet. Res. 47(6):1235-1238.
***Abstract*:** Adult ewes (17 months of age) were vaccinated against Q fever (*Coxiella burnetii*), using a formalin-inactivated whole cell (WC) phase I Henzerling strain vaccine or a chloroform methanol residue (CMR) vaccine. Nineteen pregnant ewes were placed in three categories [(i) unvaccinated, (ii) WC vaccine, and (iii) CMR vaccine] and were challenge exposed at approximately the 100^{th} day of gestation with 210,000 plaque-forming units of *C. burnetii* inoculated subcutaneously. Shedding of rickettsiae was measurably reduced, but was not prevented in vaccinated groups, as shown by inoculating ewes' placental tissues, amniotic fluid, and colostrum into mice, as well as by histopathologic lesions of placental tissues. The rickettsiae were shed in the placenta, amniotic fluid, or colostrum in 6 nonvaccinated ewes. In comparison, rickettsiae were detected in placental inoculations from 2 of 6 ewes in the WC vaccine group and 1 of 6 in the CMR group. In contrast to those in the vaccinated ewes, placentitis, high concentrations of rickettsiae in microscopic preparations, and weak lambs were typical for the nonvaccinated ewes.

1040. Brown, Dan L., Martin R. Dally, M. R. Schwartz, and G. Eric Bradford. 1987. **Feed efficiency, growth rates, body composition, milk production and milk composition of Targhee sheep selected for increased weaning weight.** J. Anim. Sci. 65:692-698.
Abstract: Lactation and growth of three contemporary lines of grade Targhee sheep developed from the same genetic base were characterized by three experiments performed over a period of 2 years. Two lines (HW and DH) had been selected for 120-day weaning weights for 24 years prior to beginning these experiments. A third line (C) was a randomly selected control. Year I experiment contrasted 10 DH with 7 C ram lambs fed to 58 kg. Year II experiments utilized 9 C, 14 DH, and 10 HW ram lambs and 11 ewes suckling twins from each line. All Year II ram lambs were born and weaned as twins, then fed to 50 kg. Mature DH and HW ewes were heavier ($P < .05$) than C ewes (65.2 and 68.8 vs 54.9 kg) and the DH and HW lambs grew faster than C lambs both before ($P < .05$) and after weaning ($P < .05$). While both DH and HW lambs drank more milk (2,419 and 2,368 vs. 2,059 $g \times d^{-1} \times pair^{-1}$; $P < .10$) only HW ewes showed a trend towards greater potential milk production than controls (HW = 2,774 vs C = 2,155 $g \times d^{-1} \times ewe^{-1}$, $P < .12$). The HW lambs tended to be leaner than C lambs ($P < .05$), but DH lambs did not differ from either line. Lambs from DH and HW lines required less post-weaning feed (121.9 and 129.3 vs. 152.0 kg, $P < .05$) and exhibited 17% and 16% greater weight per day of age at 50 kg than controls ($P < .05$). The DH line displayed lower feed:gain ratios than controls in both post-weaning trials (6.68 vs. 7.30 to 58 kg; 5.83 vs 6.24 at 50 kg; $P = .06$).

1041. Brown, Dan L. 1992. **Nutrition and wool production.** Pp. 9-12 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The relationship between sheep nutrition and wool production is summarized and discussed. In a ewe, the amount of energy needed for wool production is so small in comparison to the other animal's other physiological requirements that it is rarely defined. Protein requirements, or more accurately amino acid requirements of wool production, are provided. Given the recent wool price outlook, it is probably not worthwhile making major changes in sheep management (including nutrition) solely to favor wool growth. Fortunately, many of the nutritional factors that improve wool production also improve sustainable lamb production. Conversely, decreases in staple growth and fiber diameter can be an indicator of nutritional problems which also reduce lamb productivity and ewe health.

1042. Cassard, D. W., William C. Weir, Donald T. Torell, and J. F. Wilson. 1956. **Gains of two types of lambs.** Calif. Agric. 10(11): 6, 12.
Abstract: Lambs in this study were born at Hopland in 1952, 1953, and 1954. The two types of lambs resulted from the program of raising replacement ewes at the Station. Half of the ewes in the flock of grade Corriedales– considered best from the standpoints of appearance, weight, and wool production– were bred to Corriedale rams to produce replacement ewe lambs. The remaining ewes were bred to Suffolk rams to produce market lambs. The initial pasture periods at Hopland were 60 days, 49 days and 50 days in each of the three years, respectively. This period ended when the lambs were sorted and the fat ones shipped for slaughter. In 1952 and 1954, lambs were shipped to a ranch in Elk Grove, CA where they were then fed on Ladino clover pastures. In 1953, the feed season at Hopland was much longer and lambs were held on range feed until June 9. The difference in starting weight each year represented the faster growth before weaning by Suffolk cross lambs. The Suffolk cross wethers gained about 1.2 lbs per month faster than the Corriedale cross wethers. Suffolk wether lambs out-gained the ewe lambs of the same type; difference between sexes was significant in the first two years but not in the third. Thus, Suffolk cross lambs from whiteface ewes can be expected to gain a little faster than Corriedale cross lambs, but if both are fed to a satisfactory degree of

finish, the carcass value of the two types will not be very different.

1043. Cassard, D. W., William C. Weir, Donald T. Torell, and J. F. Wilson. 1956. **Performance of crossbred ewes.** Calif. Agric. 10(10):11-12.
Abstract: Many sheepmen who raise replacement ewes have stopped using rams of the finewool breeds and have substituted rams of medium-wool, dual-purpose breeds. To evaluate breeds, which each have their strong and weak points, it is necessary to compare them under identical environmental conditions. The performances of four types of first-cross ewes were compared for several years on the Hopland Field Station range. Dams of all ewes were Rambouillet-Merino– finewool– breeding. Sires of the four groups were Columbia, Corriedale, and Romeldale– all medium-wood, dual-purpose type– and Border Leicester, which is used extensively in this type of breeding in Australia. Production records were collected on the crossbred ewes and index figures were used to evaluate the groups. Two production indices were calculated. The first index is an expression of total or gross production of both lamb and wool; the second index is an attempt to express the ability of the type of ewe to produce total income per acre. For both indexes, the Corriedale cross was highest, followed by the Columbia cross. The Romeldale cross was lower than the Border Leicester cross for the first index but higher for the second. It appears that the Border Leicester cross is shorter-lived than the others, but this may be applicable only to the conditions at locations such as Hopland, where sheep have a rugged existence, particularly during the winter and early spring months.

1044. Center, D. Michael, and Milton B. Jones. 1984. **An improved esophageal fistula bag for sheep.** J. Range Manage. 37(5):476-477.
Abstract: The use of esophageal fistulated animals is a preferred method of collecting samples representative of the diet of grazing animals. Conventional square canvas collection bags attached to the animal's neck by two straps can be time consuming to fit to the animal, and they require the bag be removed in order to sample the collected forage. An improved collection bag was developed that can be quickly fitted to the animal and allows for easy transfer of collected forage. It consists of a fabric collar to which is attached a 2-cm-wide ring made of 10.2-cm-diameter PVC pipe, to which is attached a plastic collection bag. The improved device has worked well in open grassland, but in brushy areas the plastic bag may tear. In this situation, a heavy weight plastic bag or a nylon mesh bag could be used. A design for the device and instructions for its fabrication are provided.

1045. Choudhry, Tariq M. 1994. ***In vitro*** **fertility evaluation of cryopreserved ram semen and its correlation with relative** ***in vivo*** **fertility.** M.S. Thesis, Univ. Calif. Davis. 24 pp.
Abstract: Sperm-egg fusion is a critical event in the fertilization process. Male fertility has been estimated with the zona-free hamster ova bioassay in humans and other mammalian species. The hamster ova bioassay is significantly correlated with *in vivo* fertility (assessed by hetersopermic insemination) of fresh, cooled and frozen boar semen. These studies were designed to evaluate assay conditions for cryopreserved ram semen and to investigate the correlation between ability to penetrate zona-free hamster eggs and *in vivo* fertility. Semen from five Merino rams and pooled semen from Suffolk rams were used in hetersopermic trials. *In vivo* fertility of the Merino rams was estimated by the percentage of Merino offspring born. Cryopreserved sperm samples were washed and capacitated in culture medium containing 40 mm calcium and supplemented with 20% estrous sheep serum. Capacitated spermatozoa were coincubated with zona-free hamster ova for 5 hour; cumulus cells and zone pellucida had been removed with 0.1% hyaluronidase and 0.1% trypsin, respectively. At ten end of coincubation, eggs were washed vigorously to remove sperm attached to the plasma membrane and whole mounts prepared. After fixing overnight in Carnoy's solution (3:1 ethanol:acetic acid), the eggs were stained with orcein (1% orcein and 45% acetic acid). Eggs were examined with phase contrast illumination to assess the percentage of penetrated eggs and the number of decondensed sperm heads per egg (penetration index). The ability to penetrate zona-free hamster ova was greater in sperm washed on a Percoll gradient than in sperm washed by dilution. Preincubation time (1, 3, and 5 hours) had no effect on the penetrating ability of spermatozoa. A correlation was observed between motile sperm concentration and egg penetration. All the eggs were penetrated when the motile sperm concentration was 6 to 9 $\times 10^6$ per ml at the beginning of capacitation. Spermatozoa from 5 fertile rams penetrated 84% to 100% of the eggs. Differences in penetration index were correlated with *in vivo* fertility ($P = 0.002$, $R^2 = 0.69$). Results of these studies suggest that the zone-free hamster ova bioassay may be a useful test in the assessment of cryopreserved ram sperm fertility.

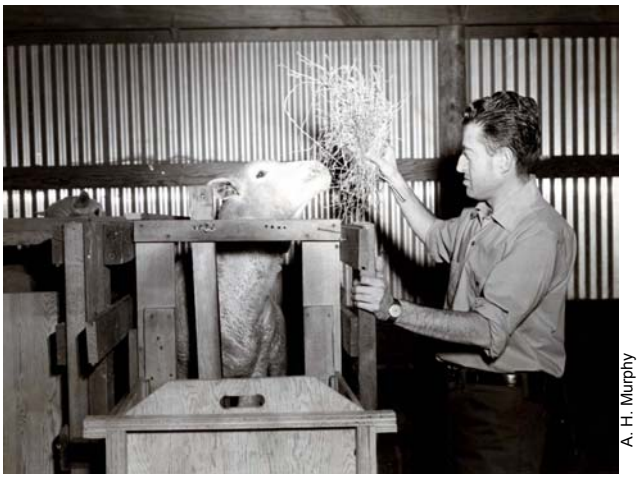
1046. Choudhry, Tariq M., Trish Berger, and Martin R. Dally. 1995. ***In vitro*** **fertility evaluation of cryopreserved ram semen and its correlation with relative** ***in vivo*** **fertility.** Theriogenology 43(7):1195-1200.
Abstract: The present study was designed to evaluate zona-free hamster ova assay conditions for cryopreserved ram semen and to investigate the correlation between ability to penetrate zona-free hamster ova and *in vivo* fertility. *In vivo* fertility was estimated for cryopreserved semen from 5 Merino rams using heterospermic insemination. Equal numbers of postthaw motile spermatozoa from a Merino ejaculate and pooled Suffolk ejaculates were mixed prior to insemination. Each Merino ejaculate was paired with the same pool of cryopreserved Suffolk semen. Relative *in vivo* fertility for each Merino ram was calculated as the proportion of offspring that were sired by the Merino (range 42% to 100%). These ejaculates also differed in their ability to penetrate zona-free-hamster ova (3.6 to 9.0 penetrated spermatozoa per ovum). Differences in penetration rate were correlated with *in vivo* fertility ($P < 0.002$, $R^2 = 0.69$). Results of these studies suggest that the zona-free hamster ova bioassay may be a useful test in the assessment of cryopreserved ram sperm fertility.

1047. Clark, Kempton K. 1987. **Ram management for one year.** P. 5 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The author, a commercial sheep producer in Zamora, CA, briefly describes his own management system for rams during an annual cycle. The author's summary word of advice is "Remember: the ram is half the flock."

1048. Cleaver, Thayer, Donald T. Torell, and Ralph R. Parks. 1959. **A plastic-roof sheep shelter.** Leaflet 118, Calif. Agric. Exper. Sta. and Extens. Service, Division of Agriculture, Univ. Calif.
Abstract: This publication describes how to build an inexpensive shelter for animals and feed, which reduces losses of lambs during inclement weather. The design, tested at the Hopland Field Station, consists of a lightweight wooden framework over which is stretched a plastic film. Roofs slopes are designed to minimize wind resistance. The framework requires approximately 1/3 board foot of lumber per 1 square foot of floor space, costing from $0.02 to $0.04 per square foot of floor space if the retail price of lumber is from $60 to $120 per thousand. Black polyethylene plastic film in 6 or 8 mil thickness is recommended because it will resist considerable abrasion. It is estimated that this material will lose half its strength in 5 to 10 years. Labor required for an 18 × 48-foot structure having a 4 ft. 6 in. overhang on each side amounted to 31.2 man hours plus a total of 3 tractor hours. Photographs and diagrams provide detailed instruction on the construction techniques and the various steps involved. The design may be adapted to larger animals.

1049. Codde, J. M., and T. Berger. 1995. ***In vivo* fertility of rams in relation to sperm-zona pellucida binding and sperm-zona pellucida penetration of ovine oocytes.** Theriogenology 44(6):901-906.
Abstract: Sperm-zona pellucida (zona) binding and sperm-zona penetration have been suggested for use as *in vitro* bioassays of fertility since both are essential steps in the fertilization process. The correlations of sperm-zona binding and sperm-zona penetration with the *in vivo* fertility of sheep were investigated in this study. *In vivo* fertility was estimated from a heterospermic insemination trial using cryopreserved ram semen. Neither zona binding, zona penetration, nor the ability to undergo an acrosome reaction was significantly correlated with the *in vivo* fertility of the rams (P = 0.78, P = 0.66, and P = 0.85, respectively). These results suggest that the zona binding and zona penetration bioassays may not be useful estimators for assessing cryopreserved ram sperm fertility.

1050. Cox, Jere. 1987. **Management of ewe lambs.** Pp. 26-28 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The author describes management methods that make it profitable to breed yearling ewe lambs successfully. Selection of replacement ewe lambs, prebreeding nutrition and veterinary care, and breeding are discussed. Pre-breeding management and breeding occur in a similar way as for older ewes, but on a later cycle. Providing adequate exercise for these lambs during gestation reduces the incidence of large lambs which may result in difficult delivery. In the 1984-85 and 1985-86 production cycles, 84% and 80%, respectively, of the ewe lambs lambed successfully, with a prolificacy of 119% and 109%. It is very important to keep these ewe lambs on a high plane of nutrition from the time they are weaned to their second lambing.


A. H. Murphy
Visiting Chilean scientist Chris Crempien offers feed to ewe, Main Barn, 1970

1051. Crempien, Christian, William C. Weir, and George Crenshaw. 1973. **Medicated feed as a preventive for pneumonia in California range lambs.** J. Am. Vet. Med. Assoc. 162(2):112-116.
Abstract: Pneumonia is one of the most important disease problems in sheep enterprises worldwide, and its incidence is higher in some regions such at the Northern California coastal area, where the disease is weaned lambs in encountered particularly during the summer months. It has been a particularly troublesome factor in experiments with weanling lambs at the Hopland Field Station. Four hundred weanling lambs reared at Hopland were used to study the effects of feeding a limited amount (0.908 kg/lamb/day) and a large amount (1.816 kg/lamb/day) of alfalfa pellets with and without chlortetracycline (CTC) alone or CTC combined with sulfamethazine for 28 days soon after weaning. Overall mortality was 7% during the 28-day feeding period and the ensuing 28-day period when all lambs were in one flock on range. The greatest mortality (11%) was among lambs on range without supplement, but some deaths occurred in all groups except those that were on the high level of feeding with both drugs included. Body weight gains were greater for the high level of feeding, particularly when the medications were included. Those lambs on the low level of feeding ate all of the feed offered, but those on the higher level of feeding took some time to become adjusted to the high feed intake. The lambs on the medicated feed adjusted more quickly and thus consumed more feed during the trial. Rectal temperatures of 36 lambs were taken on 13 days during the trial. The mean temperatures of all the lambs were increased for the first 3 days of the study. By discarding these early data, significantly lower rectal temperatures were detected in the lambs on the low level of feeding with CTC. High temperatures were found among some individual lambs on the low level of nonmedicated feed.

1052. Cushwa, W. T., G. Eric Bradford, G. H. Stabenfeldt, Y. M. Berger, and Martin R. Dally. 1992. **Ram influence on ovarian and sexual activity in anestrous ewes: effects of isolation of ewes from rams before joining and date of ram introduction.** J. Anim. Sci. 70(12):1195-1200.
Abstract: A two-year experiment was conducted to determine whether isolation of ewes from rams is necessary to achieve a high response to the ram effect and whether ewes respond as well in May as in June. The experiment was conducted at two locations with the same four treatments at each location. The four treatments differed with respect to ewe proximity to rams before mating (isolated vs. adjacent) and date of joining with novel breeding rams (May 15 vs. June 15). The proximity treatment at one location was changed in the 2nd year; teaser rams were joined with the ewes instead of being adjacent to them. Overall, 86% of the eligible ewes were judged to have responded to the ram effect. A period of isolation before mating did not increase response compared with ewes that remained adjacent to, or in contact with, rams (86 vs. 85%). Response was greater ($P < .05$) in June and in the 2nd year ($P = .05$). A physiological response, different from that generally described, was identified. Ewes ovulated approximately 8 days (8.0 ± .19 days) after joining with breeding rams. The subsequent ovulation, accompanied by estrus, occurred approximately 15 days later (15.3 ± .29 days). Eighty-five percent (87/102) of the ewes sampled responded in this manner. However, 82% (31/38) of a sample of these ewes had at least one morphologically normal corpus luteum when examined by laparoscopy 4 days after joining. It seems that these corpora lutea were not completely functional with respect to progesterone production. The ram effect can be achieved without prior isolation of ewes from rams. Although response was high in May, the best results were observed when breeding rams were introduced in June.

1053. Dally, Martin R. 1985. **Teaser rams.** The Shepherd 30(8):27.
Abstract: Teaser rams are used to stimulate ewes and synchronize ewes' estrus. Pheromones, which are specialized hormones produced by the ram and smelled by the ewe, stimulated the advancement of the breeding season. Forty-four percent of the ewes exposed to teaser rams lambed in the first seven days of lambing, while only 11% of the ewes that had not been exposed lambed during the same period. Although this method is not as effective as hormone therapy, labor requirements and expenses are not as high. This article discusses effect of pheromones on ewes, synchronization, use of intact rams, and isolation. Further research is being conducted to determine if different breeds of ewes react differently to teaser rams.

1054. Dally, Martin R. 1986. **Bagging out ewes.** The Shepherd 31(4):37.
Abstract: The term "bagging out" refers to separating ewes from the

main flock that are expected to lamb within a short period of time. The bagging out procedure involves palpating the udder in an attempt to determine how soon the ewe will lamb. Shortly before lambing, the udder becomes enlarged and will feel quite firm. An advantage of bagging out ewes before lambing is that it allows the producer to separate the ewe flock into groups needing more immediate attention and more intensive management, allowing provision of better feed and care for ewes at lambing.

1055. Dally, Martin R. 1986. **Performance of Barbados cross sheep in California.** The Shepherd 31(11):20-21.
Abstract: Because 80 to 85% of U.S. sheep producers' income is derived from the sale of lamb, any way of increasing pounds of lamb weaned per ewe would likely increase profitability. Increasing the number of lambs weaned is the most economical way of increasing the pounds of lamb weaned per ewe. At Hopland, work is being conducted on crossbreeding and selection of more prolific sheep. Both Finn-sheep and Barbados Blackbelly (a hair sheep from the West Indies) are being tested and compared with Targhee and Targhee crosses at Hopland. In 1981-82, a study compared straight bred Barbados and Targhee ewes with Barbados cross ewes when bred to Targhee rams. The Barbados ewes were consistently lighter at fall weighing, with the Targhee ewes the heaviest, and the crosses intermediate. The lamb crop expressed as lambs born per ewe present at lambing showed a marked superiority of the Barbados and Barbados cross ewes of the Targhee ewes. An effect of heterosis was noted; crossbred ewes produced 38.8% more lambs than the average of the two parent breeds. Barbados cross ewes weaned 67.9% more lambs than Targhee ewes; Barbados × Dorset-Targhee ewes weaned 59.1% more lambs than Targhee ewes. Lambs produced by Targhee ewes had highest weaning weights, followed by the B-T ewes' lambs, 54.3 and 48.0 lbs, respectively. The B-T ewes weaned 80.0 lbs of lamb per ewe, which is 43.2 lbs more lamb weaned per ewe than the Targhee ewes; the B × T-D ewes weaned 20.0 lbs more lamb per ewe than the Targhees. However, post-weaning growth rate of quarter-Barbados lambs is less than that of straight bred Targhee lambs and therefore their value as feeder lambs would be less. In a subsequent study, B-T ewes produced more pounds of lamb per ewe than Targhee ewes, 85.6 and 80.1 lbs respectively, while D-T ewes produced the least, 59.9 lbs, due mainly to poor lamb survival. Finn-Targhee ewes produced 63.5 lbs per ewe. Under Hopland conditions, B-T ewes can produce a highly satisfactory lamb crop, but quarter-Barbados lambs' lack of post weaning growth is a serious disadvantage. The extremely poor wool production of half Barbados ewes is another disadvantage. If a meat type sire were mated to the half Barbados ewes, the pre and post weaning lamb growth rate would likely be more satisfactory. In 1983, a 5-year follow-up study was initiated using quarter-Barbados ewes to see if wool quality as well as quantity can be improved, and at the same time improve lamb growth without losing the high prolificacy and lamb survival.

1056. Dally, Martin R. (Editor). 1987. **Proceedings, Sheep Breeding School.** Hopland Field Station, Univ. Calif., Hopland, CA, 53 pp.
Abstract: Fifteen short papers are contained within this Proceedings, summarizing information presented during the Sheep Breeding School at Hopland by researchers, farm advisors, flock managers, and commercial sheep producers among others. All aspects of sheep breeding and reproductive management are discussed. Other papers included discuss aspects of husbandry including pasture improvement, body condition scoring, identification, record keeping, and flock health.

1057. Dally, Martin R. 1987. **Laparoscopy examination.** Pp. 41-42 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: This summary provides a step-by-step explanation of laparoscopic examination surgery in sheep. A major advantage of laparoscopy is that repeated observation in the same ewe can be performed without causing adhesions. At the Hopland Field Station, laparoscopy has been employed to study the effects of flushing on ovulation rate, embryo survival in ewes treated with selenium, and ovulation rates of different breeds and lines of sheep. In recent years, laparoscopy artificial insemination (AI) has been performed at the commercial level within the sheep industry. An experienced operator can perform 20 laparoscopies per hour.

Mendocino County Extension advisor John Harper observes as research associate Martin Dally demonstrates laparoscopic AI procedure on a ewe at Wool Production School, April 1992

1058. Dally, Martin R. 1987. **Synchronization of estrus and out of season breeding.** Pp. 49-53 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Synchronizing ewes can be very useful when a prescribed lambing date is desired, or when a relatively short lambing period is required. It is essential in any large-scale artificial insemination program and when embryo transfer is going to be performed. It also has the advantage of providing more efficient use of feed and labor. This summary provides a discussion and comparison of three different methods for synchronizing ewes' estrus cycle: 1) the ram effect; 2) photoperiod manipulation, and 3) hormone therapy. Each method has advantages and disadvantages, and the cost and amount of labor varies greatly.

1059. Dally, Martin R. 1988. **Laparoscopic insemination: the gateway to genetic improvement.** Natl. Wool Grower 3:34-35.
Abstract: For many years artificial insemination (AI) of sheep was thought to be impractical, mainly doe to the difficulty of detecting estrus and controlling the ewe's estrus cycle. Today, with the use of progestogen and PMSG the synchronization of the ewe's estrus cycle is possible. Additionally, ram semen can now readily be frozen, which opens the door for interstate and well as international movement of semen. In 1982, Australian researchers developed a laparoscopic insemination procedure with revolutionized sheep AI technique. Conception rates using frozen semen range from 70 to 80%, when a skilled technician used the laparoscopic technique to place the semen directly into the ewe's uterus. This article describes hormone therapy that is required to synchronize estrus in ewes prior to the laparoscopic insemination procedure. The laparoscopic insemination procedure is also described in detail.

1060. Dally, Martin R., and Milton B. Jones. 1990. **Embryo survival in sheep with and without Se supplement on sulfur-fertilized pastures.** P. 41 *in:* Proc. Ann. Mtng., West. Coord. Comm. 39.
Abstract: Two-hundred eleven Targhee type ewes, 13-14 months of age, were grazed from March 29 to June 30, 1989 on subclover pastures that had been fertilized with 300 lbs gypsum per acre. Half the ewes were supplemented with 5 mg Se every 56 days during the trial. The ewes' estrus cycles were synchronized using progestogen impregnated pessaries. Seven to eight days after sponge removal, laparoscopic examination of the ovaries was performed to count corpora lutea. The number of lambs born in relation to number of corpora lutea will be used to determine embryo survival. Blood samples were collected at breeding and will be analyzed for Se levels. This is the third and final year of this trial. Embryo survival data for the current year are not yet available.

1061. Dally, Martin R., John M. Harper, and Pamela J. Tinnin (Editors). 1992. **Proceedings, Wool Production School.** Publ. 103, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA. 93 pp.
Abstract: Sixteen presentations made during the Wool Production School are summarize in this Proceedings. Topics include: sheep breeds, wool physiology, sheep nutrition, genetics, effects of diseases and parasites, physiological and environmental factors, wool grading, economics, marketing, the Wool Quality Improvement Program, artificial insemination, the Hopland long term genetics project, evaluating wool quality, shearing and handling techniques, and Australian Merinos.

1062. Dally, Martin R. 1992. **Physiological and environmental effect on wool production.** Pp. 24-31 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The effect of a sheep's physiological state and environment on wool productivity are discussed, with emphasis on the following important factors: natural seasonal variation, animal age, temperature, pregnancy, and lactation.

1063. Dally, Martin R. 1992. **Laparoscopic artificial insemination a means to improve genetics.** Pp. 64-67 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Artificial insemination (AI) of sheep by means of laparoscopy now offers producers an opportunity to make significant, rapid genetics gains within flocks. The technique of laparoscopic artificial insemination is explained in a step-by-step description. The basic economics of AI are discussed. Because the traits of wool quality and quantity are highly heritable, rapid improvements in this area are possible. However, in selecting a sire one should consider the progeny's ability to adapt to the environment. At the Hopland Field Station, laparoscopy AI has routinely resulted in conception rates of 70+%. Conception rates can vary greatly depending on semen quality, breed, management, time of year, and the technician.

1064. Dally, Martin R. 1992. **Quality wool clip essential to survival of wool industry.** Pp. 78-83 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Handling and preparation of the wool clip may become more critical in American producers' being able to market this product in the global economy. Factors in wool quality include sheep nutrition, breed, and selection. Contamination of wool from natural, acquired, and applied sources are discussed in detail. Among natural sources are colored wool fibers, which can be reduced through flock selection and removing belly wool and spots of colored wool from fleeces at shearing. Acquired contaminants include vegetable matter, polypropylene, colored fibers from other animals, and stained wool. Good management practices can reduce such contaminants. Applied sources include paint brands, marking chalk, and certain veterinary products. Alternatives for such products are discussed.


Jack Kelly Clark

Assistant shepherd Patrick Hanson holds newly-shorn fleece, April 1996

1065. Dally, Martin R. 1992. **Australian Merinos and their wool.** Pp. 89-90 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Characteristics of Australian Merino sheep are described and discussed, as is the history of Merinos in Australia. Merino rams have been known to produce 48-pound fleeces, as compared to 16 to 23-lb fleeces for most U.S. wool breeds. Between 75% and 85% of Australia's sheep are Merinos. Within the breed, wool categories of fine, medium, and strong wool can be defined. The history and characteristics of Spanish Merinos and Saxon Merinos in Australia are summarized. Later development of the Peppin Merino, the South Australian Strong Wool strain, and the Extra-Strong Wool strain are described.

1066. Dally, Martin R., M. B. Jones, and E. J. DePeters. 1994. **Supplemented native range and subclover pastures improve lambing rates.** Calif. Agric. 48(2):14-17.
Abstract: Grazing ewes on mature subclover pastures shortly before and during the breeding season was as effective as grazing them on native range pastures and supplementing with alfalfa pellets at a rate of 2 pounds per day. Ewes on both kinds of pasture produced 21% more lambs than ewes grazed on unsupplemented native pastures. The article discussed results from studies at Hopland in terms of subterranean clover and protein levels in forage, weight gain and lambing rates, and the economics of grazing ewes on improved rangelands.

1067. Dally, Martin R., and G. Eric Bradford. 1995. **Evaluation of Merino and U.S. genotypes for wool and lamb production.** *In:* Proc. Ann. Mtng., West. Coord. Comm. 39, Hopland, CA.
Abstract: *Unavailable for publication.*

1068. Dally, Martin R., and John M. Harper. 1996. **Development and evaluation of superfine sheep.** P. 43 *in:* Proc. Ann. Mtng., West. Coord. Comm. 39, Laramie, WY, Jun. 25-28.
Abstract: The objective of this project is to develop and evaluate a superfine (< 20.6 μm) line of sheep in a high winter rainfall annual

grassland system. In August 1995, 40 yearling and 23 mature ewes were scheduled to be artificially inseminated to 3 superfine Merino rams. However, the progesterone sponges were inadvertently pulled before scheduled, resulting in cancellation of the AI program. Therefore the ewes were single sire mated to 4 ram lambs (average 21.05 μm at 16 mos. of age). Only two of the ram lambs sired lambs during the single sire mating. The cancellation of the AI program was a major setback to the breeding program. This coming year, 77 ewes are scheduled to be artificially inseminated to 4 Australian Merino rams.

1069. Dally, Martin R., and John M. Harper. 1997. **Development and evaluation of superfine sheep.** P. 38 *in:* Proc. Ann. Mtng., West. Coord. Comm. 39, Laramie, WY.
Abstract: This project is still in the developmental stage. The only data available to date on the 1997 yearling ewes is grease fleece weight, staple length, and yearling body weight, 4.9 kg, 10.0 cm, and 56.6 kg, respectively. In August 1996, laparoscopic AI was performed on 78 Merino cross ewes. An overall conception rate of 80.8% was obtained. Semen from 7 Australian and one New Zealand Merino was used; individual sire conception rates ranged from 64% to 100%. The 63 ewes that lambed as a result of AI averaged 1.78 lambs born. In August 1997, 118 ewes are scheduled to be AI'd with semen from 5 Australian Merino rams including 4 horned rams, range 15.7 to 18.5 μm. One polled ram (22.7 μm) will be used on a very limited number of ewes in an attempt to increase the poll gene frequency in the population.

1070. Della Rosa, R. J., S. A. Book, H. G. Wolf, and W. M. Longhurst. 1969. **Maternal-fetal transfer of injected Cesium-137 and Iodine-131 in deer and sheep.** Pp. 117-120 *in:* Radiation Biology of the Fetal and Juvenile Mammal. Proc. 9th Ann. Hanford Biology Symposium, Richland, WA, May 5-8.
Abstract: Four pregnant sheep (*Ovis aries*) and three pregnant deer (*Odocoileus hemionus columbianus*) in the latter third of gestation were intravenously injected with ~50 μCi of ^{131}I and ~15 μCi of ^{137}Cs. Blood samples were taken 11 times over the next 48 hours to determine plasma disappearance rates; the animals were then sacrificed, and determinations of radionuclide distribution in maternal and fetal tissues were made. Radionuclide content in the tissue samples was determined by different gamma ray spectrometry using a 20- by 10- cm NaI (Tl) crystal and multichannel analyzer. An automatic gamma-well counter was used for determinations of radionuclide content in blood (plasma) samples. Percentage of administered dose was determined by spectrum stripping and computer analysis of data. The disappearance rate of the radionuclides from the blood was similar in both species. There was minimal transfer of ^{137}Cs across the placental barrier. Less than 2% of the injected ^{137}Cs was found in the whole fetuses of both species. However, ^{131}I was shown to be efficiently transferred across the placental barrier in both species. The terminal concentration of ^{131}I in fetal plasma was 3 to 5 times greater than that in the maternal plasma of either species.

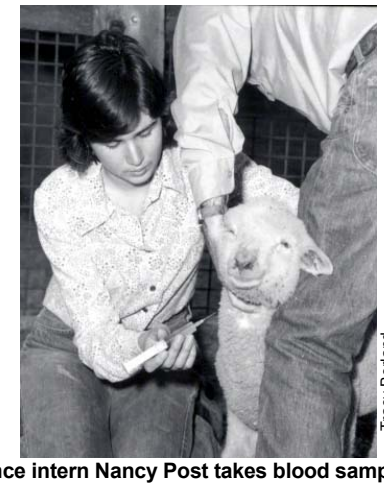
1071. DePeters, Edward J., Martin R. Dally, A. A. Alwash, and P. Therkelsen-Tucker. 1985. **The use of supplement blocks for sheep grazing dry, annual pastures in California.** J. Range Manage. 38(4):291-295.
Abstract: The objective of this study was to evaluate the use of supplemental blocks on body weight change, blood parameters, and lambing performance of ewes grazing dry, annual grasses during the summer prior to and during breeding. Two experiments were conducted in successive years to compare performance of unsupplemented control (C) and supplemented (S) Targhee ewes. In the first season, yearling ewes were used while aged ewes (2 or 4 years) were used during the second season. During the first year, supplemented ewes lost less body weight during the dry grazing season than C ewes. However, no lambing performance difference was found between C and S groups. During the second year, supplemented ewes maintained their body weight over summer while C ewes lost weight. In addition, lambing performance (multiple births) was higher for S than for C ewes. Supplementation of ewes with blocks containing molasses, urea, protein, and minerals required little labor input. However, based on lambing performance, it is unlikely than supplementation would be economically profitable under the range conditions utilized in these trials.

1072. Douglas, James R., Norman F. Baker, and William M. Longhurst. 1956. **Trial with Di-phenthane-70 on stomach and intestinal nematodes in sheep.** J. Am. Vet. Med. Assoc. 128(7):361-362.
Abstract: Previous reports of use of the drug di-phenthane-70 [*bis* (5-chloro-2-hydroxyphenyl) methane] in sheep have reported its utility in removing the tapeworm *Thysanosoma actiniodes* from sheep, but suggested it is not as reliable as other tenaicides in removing *Moniezia expansa* from sheep. These reports have not mentioned its effect on stomach and intestinal nematodes. While it is currently being employed to remove tapeworms from sheep, there have been unsubstantiated reports of its nematocidal activity in ruminants. In this experiment, when administered at the rate of 6 grams/40-lb lamb, it did not significantly reduce the numbers of nematodes in the abomasum or small intestine. It also failed to effect a significant reduction in the number of eggs produced by the female worms.

1073. Douglas, James R., Norman F. Baker, and William M. Longhurst. 1956. **The relationship between particle size and anthelmintic efficiency of phenothiazine.** Am. J. Vet. Res. 17(63):318-323.
Abstract: Phenothiazine is unique in its action in that it acts as an anthelmintic, it suppresses egg production of many nematodes, and also is toxic to free-living stages of nematode larvae in the feces of treated animals. Experiments using natural nematode infections in lambs and artificial infections with *Nematospiroides dubius* in mice demonstrated that anthelmintic efficiency of phenothiazine is inversely proportional to the diameter of the particles. Particles larger than 140 μ in diameter were found to be ineffective when administered to sheep in a single dose. A preparation with a mean particle diameter between 40 and 50 μ was 70% effective and a preparation with a mean particle diameter between 1 and 2 μ was 95% effective. Phenothiazine incorporated in the diet of infected mice confirmed the observations on lambs. It was further shown that suppression of ovogenesis in the nematodes in these experiments was also inversely proportional to the diameter of the phenothiazine particles. In the sheep, particularly, this differential effect was clearly evident.

1074. Douglas, James R., Norman F. Baker, and William M. Longhurst. 1957. **The effect of divided dosage on the anthelmintic efficiency of phenothiazine in lambs.** J. Am. Vet. Med. Assoc. 131(8):369-371.
Abstract: Phenothiazine administered therapeutically to sheep and cattle has usually been given as a single dose in a drench, bolus, or capsule. In an attempt to simplify the procedure and avoid individual handling of animals, phenothiazine has been mixed with various feeds, mineral supplements, flavorings, and other additives. These mixtures are usually intended to provide a therapeutic dose to be consumed in one day. However, sheep and cattle often will require 3 to 5 days to ingest this full dose. Consequently, it has been recommended that the dose be divided into 2, 3, or 4 equal portions to be fed on successive days, as is done with horses treated for strongyles. It was postulated that division of a ruminant therapeutic dose might markedly impair its anthelmintic efficiency. Therefore, this work specifically investigated the effect of administration of

divided doses of phenothiazine to lambs. Administration of a 25-gram dose of phenothiazine to lambs over periods of 1, 3, 5, and 7 days showed that anthelmintic efficiency was decreased in an essentially linear relationship. Anthelmintic efficiency dropped from 65%, when the dose was given at one time, to zero when it was given in equal daily doses over a period of 7 days.


Tracy Borland

Animal Science intern Nancy Post takes blood sample from ewe, Winter 1976

1075. Douglas, James R., Norman F. Baker, and Paul H. Allen. 1959. **Trial with a new organic phosphate as an anthelmintic in sheep.** J. Vet. Res. 20(76):442-444.
Abstract: The recent widespread interest in organic phosphorus compounds as insecticides and miticides, particularly with respect to their systemic activity in mammals, has led several investigators to explore their possible value as anthelmintics. An organic phosphate compound, Dowco 105 [0-methyl 0-(tert. butyl-2-chlorophenyl) ethylphosphoramidothate] was found to have marked anthelmintic activity against most species of nematodes in abomasum and small intestine of lambs. A dosage rate of 200 mg/kg of body weight gave an overall anthelmintic efficiency of 93%. When the dose was reduced to 75 mg/kg, anthelmintic efficiency dropped to 55%. It is considered that compounds of this class show promise as anthelmintics for use in ruminants and possibly other species of animals.

1076. Douglas, James R., Norman F. Baker, and William M. Longhurst. 1959. **Further studies on the relationship between particle size and anthelmintic efficiency of phenothiazine.** Am. J. Vet. Res. 20(74):201-205.
Abstract: In an earlier paper, the authors reported experiments which demonstrated that the anthelmintic efficiency of phenothiazine in range lambs at Hopland was inversely proportional to the diameter of the particles. In that report, the commercial phenothiazine powder (N.F. grade) referred to as "medium" was estimated to have mean particle diameter of between 40.0 and 50.0 μ. Further examination of this material, using the air permeation technique, established that the mean particle diameter was actually 12.8 μ. The purpose of these trials was to determine the anthelmintic efficiency of samples of phenothiazine of different mean particle diameters and to construct a curve showing the relationship between particle size and anthelmintic efficiency in lambs. There was found to be a linear relationship between specific surface area of phenothiazine preparations and anthelmintic efficiency, within the approximate range of 5,000 to 25,000 sq. cm. per gram. This represents a range of approximately 1 to 10 μ mean particle diameter and 98% to 63% efficiency. Within these limits, an increase in specific surface area of 619 sq. cm. per gram resulted in a 1% increase in efficiency. The anthelmintic efficiency of a purified phenothiazine preparation with a mean particle diameter of 4.8 μ was found to be approximately equal to that of N.F. material with a mean particle diameter of 1.9 μ.

1077. Dunbar, John R., R. S. Knight, and W. J. van Riet. 1987. **Body condition scoring.** Pp. 6-10 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Body condition scoring, a technique developed in Australia to develop the fatness or nutritional condition of ewes, is described. Target body condition scores for different points during the annual cycle are given. Adequate nutrition of ewes, as evidenced by body condition, is essential for optimum productivity. Data on lambs born per 100 ewes, as related to body condition score at mating, is provided.

1078. Erhard, H. W., Edward O. Price, and Martin R. Dally. 1998. **Competitive ability of rams selected for high and low levels of sexual performance.** Anim. Sci. 66(2):403-408.
Abstract: The objective of this study was to determine any differences in the competitive ability of rams differing in levels of sexual performance. Twenty sexually experienced Targhee-type rams were pre-selected from a population of 95 males for exhibiting relatively high and low ejaculation rates when individually exposed to oestrous ewes for 30 min. Each of 10 high performers (HP) were paired with each of 10 low performers (LP) on three occasions when competing for food (after food deprivation) and twice when competing for an oestrous female. Tests were 5 minutes in duration. Food-deprived HP and LP rams were equally aggressive when competing for a source of food that could only be accessed by one ram at a time. Time of feeding by HP and LP rams did not differ. HP rams spent more time with the oestrous ewe and attained more mounts in a greater number of pairings than LP rams even though HP and LP rams did not differ in number of successful agonistic interactions (active displacements and successful defenses) when competing for the ewe. It was concluded that HP and LP rams, taken as groups, do not differ in their basic competitive ability and that the greater mating success of HP rams can be explained by their higher levels of libido.

1079. Estep, D. Q., Edward O. Price, S. J. R. Wallach, and Martin R. Dally. 1989. **Social preferences of domestic ewes for rams (*Ovis aries*).** Appl. Anim. Behav. Sci. 24:287-300.
***Abstract*:** A series of four experiments was performed to investigate the social preferences of 16 domestic ewes for potential mating partners. Ewe preferences were assessed by measuring the time spent in proximity to each of two restrained rams and/or 1 or 2 restrained ewes in 5- or 20-minute tests. In the first experiment, it was shown that estrous ewes preferred to be in proximity to rams, while anestrous ewes preferred other ewes. The second experiment showed that ewe preferences were strongly correlated with the rates of ram sexual solicitations and that ewes preferred older, larger rams over younger, smaller rams. The third experiment demonstrated that ewes preferred rams that had a history of higher sexual performance, independent of their rates of sexual solicitation. The fourth experiment demonstrated that the presence of older estrous ewes interacting with rams can enhance the attractivity of some, but not all, rams. Taken together, these results suggest that ewes can have strong preferences for potential mates and that these preferences may account in part, for the findings that older, larger more sexually active rams tend to be more reproductively successful. These findings suggest specific management practices which could improve breeding efficiency in domestic flocks.

1080. Galmez, J., E. Santisteban, E. Haardt, C. Crempien, L. Villalta, and Donald T. Torell. 1970. **Performance of ewes and lambs fed broiler litter (Abstract).** J. Anim. Sci. 31(1):241.
Abstract: Tests utilizing broiler litter as livestock feed are reported.

Performance of Group 1, fed 63% broiler litter (poplar chip base), 35% beet pulp, and 2% salt, was compared with Group 2 fed 87% alfalfa hay, 11% beet pulp, and 2% salt. Both rations were fed *ad libitum* to whiteface pregnant ewes for means of 36 and 41 days (N.S.) pre-partum. Both rations were calculated to contain 52% total digestible nutrients (TDN). Broiler litter contained 21.7% crude protein, 31.1% crude fiber, and 9.7% ash. Single lamb birth weight (kg), adjusted 90-day weight (kg) and average daily gain (ADG) (g) were, respectively: Group 1, 4.78, 19.72, 171; Group 2, 4.39, 17.57, 146. Differences were not significant. Ewe consumption (kg/day) pre-partum was 2.4 for Group 1 and 2.5 for Group 2. In a separate trial, 40 weaned whiteface lambs were divided into five groups. Four groups were fed fattening rations containing 68, 58, 48, and 38% broiler litter (ricehull base with 27.4% crude protein, 12.7% ash, and 4.146 kcal/g) plus ½ beet pulp and ½ ground oats + 2% salt. The other groups was fed baled alfalfa hay. All rations were fed *ad libitum*. ADG (g) and efficiency (feed/gain) were, respectively: 170, 5.36; 174, 5.26; 186, 4.46; 208, 4.30; 84, 25.03. There was no significant difference among the broiler litter treatments for ADG but the difference between broiler litter and alfalfa was significant ($P < .01$).

1081. Glenn, John S., Martin R. Dally, Darrell E. Behymer, and M. N. Oliver. 1991. **Evaluation of enzyme-linked immunosorbent assay antibody response in rams following *Brucella ovis* vaccination.** SID Sheep Res. J. 7(1):16-18.
Abstract: The development and increasing use of enzyme-linked immunosorbent assay (ELISA) to detect antibody response to *Brucella ovis* has raised concerns about interpretation of results in animals that had been previously vaccinated for *B. ovis*, since ELISA positive animals are usually culled. This study was done to determine the pattern of *B. ovis* ELISA titers following vaccination. Two groups of 9-month-old replacement ram lambs were vaccinated with one of two commercially available *B. ovis* bacterins and maintained with a third group of nonvaccinated controls. Both vaccinated groups were given booster inoculations five weeks after the first injection. During a 29-week period, serum samples were collected 17 times and tested by ELISA. Mean values for percent ELISA showed Group 1 vaccinates ELISA negative (<30% absorbency) one week post-vaccination, ELISA positive (>39% absorbency) from two through eight weeks, ELISA suspect (30-39%) at 12 weeks, and ELISA negative from 17 weeks through 29 weeks. Mean values for percent ELISA in Group 2 vaccinates remained in the negative category throughout the trial except for week 8, when mean value was in the suspect category. Mean values for the control group stayed within the negative category for the entire period. Results of the study suggest that use of the ELISA for detecting infection with *B. ovis* should be avoided for at least four months following vaccination with currently available commercial *B. ovis* vaccines.

1082. Goldman, Marvin, William M. Longhurst, R. J. Della Rosa, Norman F. Baker, and R. D. Barnes. 1965. **The comparative metabolism of strontium, calcium and cesium in deer and sheep.** Health Physics 11:1415-1422.
Abstract: Fallout measurements from animals raised in the same area at the same time suggest that ^{90}Sr and ^{137}Cs body concentrations result from several factors. The fallout deposition rate is known to be directly correlated with the precipitation pattern. Radionuclide incorporation into forage plants is also related to species and plant phenology. Subsequent levels of radioactive fallout in ruminants are related to the quality of the diet consumed, timing of bodily development, the fallout level in the diet at that time, and the intrinsic metabolic characteristics of the animal species as related to particular radionuclides. Estimates of these variables for the radioecologic studies vary and are often difficult to quantitate. Of primary concern is the relative importance of dietary composition and animal discrimination in relation to radionuclide metabolism. The purpose of this study was to compare these two factors in a semiquantitative manner. Six deer and six sheep were fed either alfalfa (calcium 0.97%, calcium/phosphorus = 5.1) or a pelleted ration (calcium 0.68%, calcium/phosphorus = 0.9) for two weeks prior to and 30 days following a single intraruminal injection of $^{85}Sr + ^{47}Ca + ^{137}Cs$. Weekly whole-body gamma spectrometry and post-sacrifice measurements on portions or skeleton, gastrointestinal tract, viscera, skin, and muscle mass were performed. The observed ratio (OR) ($^{85}Sr/^{47}Ca$) total body or bone was 0.5 in sheep and deer fed pellets, while on alfalfa the OR was 0.4 for sheep and 0.3 for deer. The dietary calcium level was approximately inversely related to the percent radionuclide uptake while the difference in OR appeared phosphate-dependent in both species. ^{137}Cs was retained with an average biologic half-period of 17 days in all animals.

1083. Gonzalez, Gonzalo E. 1982. **Factors affecting estimates of genetic parameters for economic traits in sheep.** Ph.D. Dissertation, Univ. Calif. Davis. 207 pp.
Abstract: Genetic parameters were estimated for birth, 120-day and 450-day weights, fleece weight, staple length, wool grade, number of lambs born and number weaned per ewe lambing, kilos born and kilos weaned, and survival of lambs (BW, 120W, 450W, FW, SL, G, LB, LW, KB, KW, S), and in a population of grade Targhee sheep kept in two locations: Davis, with adequate feed year-round, and Hopland, annual grassland range with a 6-month or longer dry season. Data came from 8 lines as follows: DW, DT, and DC; HW, DH, HT, HC1, and HC2, where D or H indicates location (Davis or Hopland); W, selection for 120W: T, selection for multiple births; and C, unselected control. Line DH was at Hopland but was sired by selected DW rams. The maximum number of records (6,840) analyzed was for BW and 120W from male and female lambs; for all other traits only females were considered. Data were collected 1959-1980 and represented 568 sires and 2,327 dams. Analyses were done within lines, except for pooling HW and DH and HC1 and HC2 for time trend analysis. Diagonal MINQUE techniques with models including year, dam age, sex, and type of birth and rearing (fixed), and sire and dam (random) were used to estimate variances, and from them heritabilities, phenotypic and genetic correlations, and repeatabilities were obtained. All parameters were higher at Davis than at Hopland except for categorical traits where differences were not clear. Females showed higher heritabilities than males for BW and 120W in both locations, and singles higher than twins at Davis but not at Hopland. Positive genetic trend was detected for 120W ($P < .05$) and BW, but no trend was detected for the variances. Heritabilities for BW, 120W, 450W, FW, SL, G, LB, LW, KB, KW, and S were .31, .30, .73, .78, .59, .68, .05, .21, .16, .34, at Davis and .25, .22, .47, .53, .34, .54, .09, .22, .13, .21, .23 at Hopland. When selected and control lines were compared, no consistent effect of selection on estimates was detected.

1084. Gonzalez, G. E., G. Eric Bradford, and Thomas R. Famula. 1982. **Effects of selection and environmental factors on estimates of genetic parameters for birth and 120-day weights in sheep (Abstract).** J. Anim. Sci. 55(Suppl. 1):148.
Abstract: Genetic parameters were estimated for birth and 120-day weights in a population of grade Targhee sheep kept in two locations: Davis, with adequate feed year round, and Hopland, annual grassland range with 6 months or longer dry season. Data came from 8 lines as follows: DW, DT, and DC; HW, DH, HT, HC1, and HC2, where D or H indicates location; W, selection for 120-day weight; T, selection for multiple births; C, unselected control. Line DH was at Hopland, but sired by selected DW rams. 6,840 records from ram and ewe lambs with both birth and 120-day weights were used. Data were collected 1959-1980, and represented 568 sires and 2,327 dams. Analyses were done within lines, except for pooling HW and DH, and HC1 and HC2, for time trend analyses. Mixed models include

year, dam age, sex and type of birth and rearing (fixed) and sire and dam (random) were used to estimate heritabilities, phenotypic and genetic correlations, and repeatabilities (as a trait of the dam). Variances, heritabilities, repeatabilities, and correlations were in all cases higher at Davis than at Hopland. Average h^2 values for birth and 120-day weight were .31 and .30 at Davis and .25 and .22 at Hopland. Control lines gave higher estimates of additive variance and heritability than selected lines for both traits at Hopland, but the reverse was true at Davis. Heritability estimates from single and twin data were similar at Hopland, but singles gave considerably higher estimates at Davis. Data from females gave higher estimates of heritability than those from males for both traits in both environments. Variances were computed from data grouped into four consecutive 5-year periods. The estimates fluctuated considerably, but there was no consistent evidence for a change in genetic or phenotypic variance over the course of the experiment.


Guy E. Connolly

Principal shepherd John Hays with lamb, March 1975

1085. Gross, S. J., E. J. Pollak, J. G. Anderson, and Donald T. Torell. 1978. **Incidence and importance of subclinical mastitis in sheep.** J. Anim. Sci. 46(1):1-8.
Abstract: The incidence of a positive California Mastitis Test (CMT), indicative of subclinical mastitis, was studied in a flock of purebred Targhee ewes from four selection lines. The incidence of positive CMT was found to be random at lambing with respect to age and line of ewe, number of lambs born and weaned, and sex of lambs, but at docking (3 to 7 weeks after lambing) increased with increasing age of ewe and number of lambs born. The effect of CMT score on total weight of lamb weaned was examined in the Targhee ewes and in a flock consisting of purebred and crossbred ewes of several types mated to Suffolk rams. CMT score of the ewe at lambing was not a significant source of variation in total weight weaned, but variation in score at docking approached significance in both flocks. There were indications that positive CMT scores were associated with lamb losses, although it was not possible to tell if mastitis was a cause or an effect of the lamb loss. Line and age of ewe (selection experiment), number of lambs born and weaned, and sex of lambs were all significant sources of variation in total weight of lamb weaned.

1086. Groverman, Frederick A. 1987. **Vaccinations and culling.** P. 14 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The author provides a brief outline of vaccinations and culling criteria that are useful to sheep producers. Both vaccination schedules and culling are based on management goals and objectives.

1087. Groverman, Frederick A. 1992. **The effects of disease and parasites on wool growth.** Pp. 21-23 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Diseases, fly strike, and both internal and external parasites that affect wool growth are summarized. Management of the sheep's environment is critical if maximum wool growth and quality of fleece is to be accomplished. Early recognition and control of disease states requires vigilance. Routine inspection and observation with planned therapy for sheep for control of external parasites is important. Dealing with internal parasitic disease is more difficult. The use of fecal egg counts may be a crucial step in judicious and effective, economical control of gastrointestinal parasites.

1088. Harker, K. W., Donald T. Torell, and G. M. Van Dyne. 1964. **Botanical examination of forage from esophageal fistulas in cattle.** J. Anim. Sci. 23(2):465-469.
Abstract: A major problem in grassland research has been to determine what plants or parts of plants animals actually eat. Because of the masticated condition of forage collected from esophageal fistula, the number of points needed when estimating dry weight from these samples may differ from the number needed when working with coarser material in hand-clipped samples. This experiment was undertaken to determine observer variation and number of microscopic points necessary for an established degree of accuracy when determining botanical composition on a percent dry-weight basis. The microscopic point method of botanical analysis gave a satisfactory estimate of species composition on a percent dry-weight basis in this two-component mixed forage sample collected by esophageal-fistulated technique. The Y = X relationship was nearly as accurate as a linear, quadratic, or cubic regression equation through the origin for this particular two-component mixture where Y = percent weight and X = percent points. Even though there were no significant differences among observers, there was a significant weight × man interaction. Two of the observers were more consistent and required one-half as many points as the other two for the same degree of accuracy. Multiple comparison test shows that estimates in one and possibly two weight groups were significantly different from the other groups. Four hundred points estimated percent dry matter at 90% confidence limit to within 20% of the mean if the weight is 16% to 30%, to within 10% of the mean between 30% and 50% weight, and to within 5% of the mean from 50% to 95% weight.

1089. Harper, John M. 1992. **Sheep breeds and their wool.** Pp. 1-5 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The history, development, and wool characteristics of the dominant breeds of sheep in North America are summarized and discussed. Four major types of sheep production worldwide are described: fine wool production, dairy production, mountain or range sheep production, and lowland lamb production. In terms of wool production, five main categories can be defined: hair, carpet or coarse wool, long wool, medium or crossbred wool, and fine or Merino wool. A table of wool characteristics for some 35 sheep breeds in the U.S. is included.

1090. Hays, John. 1987. **Sheep identification.** Pp. 15-17 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Identifying sheep with external marks can be a very useful

practice for sheep management, and it can prove livestock ownership. Methods and materials can be temporary or long-lasting. Legibility or ease of reading is important for quick observation. The following methods are briefly described: earmarks and ear notches, ear tags, tattoos, hot and cold branding, and temporary marks with chalk, dyes, etc.

1091. Hintz, H. F., H. J. Heitman, William C. Weir, Donald T. Torell, and J. H. Meyer. 1966. **Nutritive value of algae grown on sewage.** J. Anim. Sci. 25(3):675-681.
***Abstract*:** Algae have been used for many purposes. Marine algae have long been used as fertilizer, livestock feed, and human food, particularly in Asia. Unicellular forms of algae have been used to purify sewage and reclaim waste waters. These studies were to determine the nutritive value of algae grown on sewage when fed to pigs, cattle, and sheep. The predominant species of algae grown on sewage were *Chlorella* spp., *Scenedesmus obliquus*, or *S. quadricauda*, depending upon the season. In the feeding trials, algae had to be pelleted with other feeds to insure consumption and prevent sorting. Algae contained 51% crude protein, which was 73% digestible when fed to cattle and sheep, but only 54% digestible when fed to pigs. The digestible energy content for cattle and sheep was 2.6 kcal/gm. Two feeding trials indicated that algae supplied adequate protein to supplement barley for growing-finishing pigs. Alfalfa-algae pellets resulted in higher gains than alfalfa pellets when fed to lambs on dry summer range. Although algae grown on sewage are not a high-energy feed because of high ash content and low digestibility of the nonprotein, non-fat organic matter, it appears to have potential as a livestock feed because of the high content of protein, plus significant amounts of carotene, phosphorus, calcium, and trace minerals.

1092. Holmes, Lisa N., Edward O. Price, Martin R. Dally, and Samoa J. R. Wallach. 1989. **Fostering lambs by odor transfer: two-lamb substitution.** Appl. Anim. Behav. Sci. 24:247-257.
Abstract: Odor specific to individual lambs enables ewes to discriminate between their own and alien offspring. Previous research has demonstrated that many postpartum ewes will adopt a single alien lamb in addition to their own natural lamb if the alien lamb is wearing a jacket impregnated with own-lamb odor ("add-on" odor transfer fostering technique). This study investigated whether a high percentage of ewes will adopt extra lambs if their own natural young is exchanged for two alien lambs (two-lamb substitution). Cloth stockinettes were placed on the natural lambs of 47 multiparous ewes shortly after parturition. Forty-eight to 72 hours later, 27 ewes that had given birth to single lambs and 20 ewes that bore twins were given two alien lambs in exchange for their own offspring. Approximately half of the ewes in each group received alien lambs wearing jackets impregnated with own-lamb odor (experimental odor transfer group); the remaining ewes received aliens wearing their own jackets (control group). Standard acceptance tests were conducted daily for 5 days. Only 14.3% of the experimental (odor transfer) ewes that bore single young accepted both alien lambs in exchange for their own. However, 90% of the experimental ewes that bore twins accepted both aliens. Control ewes had lower adoption rates of alien lamb pairs. Ewes bearing single young tended to accept only one lamb. Experimental ewes that received siblings (twins) were more likely to accept both alien young than ewes that received non-siblings (57.1% vs. 30% respectively). Ewes that bore single lambs were more likely to accept a single alien lamb if they were presented with non-sibs than sibling pairs (84.6% vs. 42.9% respectively). It was concluded that two-lamb substitution via the odor transfer fostering technique is inferior to the add-on procedure for increasing the number of lambs reared by ewes. However, it is an effective method for replacing twin sets that have died.

1093. Jones, Milton B., D. T. Rendig, Donald T. Torell, and T. S. Inouye. 1982. **California study shows importance of sulphur-fertilized forage to lambs.** Sulphur in Agric. 6:2-3.
Abstract: In a two-year study, subclover-grass and ryegrass pastures were fertilized with sulfur at rates from 0 to 80 lbs/acre. The forage was cut, dried, ground, and pressed into pellets, which were then fed to lambs. Sulfur concentrations ranged from 0.13% to 0.24% in the clover-grass forage, and 90% of the maximum average daily gain (ADG) was reached at the 0.19% S level. In the ryegrass forage, sulfur concentrations ranged from 0.09 to 0.22%, and ADG was still increasing at the highest level of applied sulfur. In subsequent trials, lambs were allowed to graze directly on pastures fertilized with sulfur and on unfertilized controls. For the entire season, lambs on ryegrass plot without sulfur gained an average of about 47 lbs, while those on plots fertilized with 80 lbs S/acre gained 59 lbs.


Guy E. Connolly

Agronomist Milton Jones prepares to weigh lamb in Main Barn, 1983

1094. Jones, Milton B., Montague W. Demment, Charles E. Vaughn, G. P. Deo, Martin R. Dally, and D. Michael Center. 1990. **Effects of phosphorus and sulfur fertilization on subclover-grass pasture production as measured by lamb gain.** J. Prod. Agric. 3(4):534-539.
Abstract: Establishment and maintenance of highly productive subclover (*Trifolium subterraneum*) pastures in northern California are often dependent on fertilization with P and S. Little work has been reported, however, on lamb growth responses to P and S applications on subclover. The objectives of this study were to measure the effect of P and S fertilization of subclover-grass pasture on forage production, botanical composition, average daily gain (ADG), lamb gain per acre (LGA), and sheep grazing days after lambs were removed, and to relate animal weight gains to botanical and chemical composition. Lambs were weaned in late February at approximately 60 days of age, with an average weight of 47 lbs, and placed on 1-acre pastures. There were eight treatments: four levels of P (0 to 50 lbs/acre), at two levels of S (0 and 88 lbs/acre), replicated twice. Lambs were set-stocked with an equal forage allowance (pounds forage per lamb) across treatments. The experiment was repeated for 6 years. There were significant differences in results between the check and applied P treatments, but not between the three P application rates with or without S. Therefore, the three P treatments were combined, as were the three PS treatments, for comparison with the check and S-only treatments. Fertilization with P and S increased ($P < 0.05$) ADG, percent subclover, forage N (protein), and decreased ($P < 0.05$) fiber in the first years of the study. Differences were not apparent later. Multiple regression and pathway analysis of the data indicated that percent subclover in the pasture, and the associated increase in N and decrease in ADF, were the most important factors contributing to ADG. Average 6-year

forage on offer was 1000, 1440, 1470, and 1630 lbs/acre (LSD [0.05] = 99), while the LGA values were 250, 380, 410, and 440 lb (LSD [0.05] = 33) for the check, P, S, and PS treatments, respectively. Subsequent to the lamb use there were averages of 129, 275, 288, and 296 additional sheep days per acre grazing (LSD [0.05] = 16) for the respective treatments. Increased forage and subclover production and % N were the most important factors influencing LGA. Under the conditions of this study, grazing early-weaned lambs on subclover pasture fertilized with P and S appeared to be very worthwhile.

1095. Larson, Stephanie. 1992. **Development of wool follicles.** Pp. 6-8 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The anatomy and physiology of wool development in sheep is summarized, beginning with follicle development in embryonic lambs. The structure of the wool fiber itself is described in detail.

1096. Larson, Stephanie. 1992. **Wool grading.** Pp. 32-35 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Systems of evaluating wool quality are summarized, including the British spinning count system and the micron system. Various methods of obtaining fiber diameter measurements are explained, as is grading according to staple length. Grading systems and variability limits are given in tabular form.

1097. Lasslo, Laurel L. 1982. **Direct and correlated responses to selection for weaning weight in sheep in two environments.** Ph.D. Dissertation, Univ. Calif. Davis. 158 pp.
Abstract: Selection for 120-day weight was initiated in 1961 in two flocks from a common base population of grade Targhee sheep. At Davis, sheep were maintained on a good plane of nutrition on irrigated pasture or in drylot. At Hopland, they grazed on an annual grassland range. Mean mature weights of base population ewes were approximately 70 and 61 kg at Davis and Hopland respectively. Selected (DW) and control (DC) lines were maintained at Davis through 1977. Selected (HW) and replicate control (HC1 and HC2) lines and a line (DH) mated to the DW selected rams were maintained at Hopland through 1980. The Hopland replicate controls did not differ and data were pooled (HC). The overall control line mean 120-day weights on a female, single, mature dam basis were 33.2 and 30.4 kg at Davis and Hopland respectively. Direct response was greater at Davis than at Hopland: DW-DC = .52 ± .07; HW-HC = .15 ± .03; DH-HC = .22 ± .04 kg per year. These results show that genetic improvement made on a higher plane of nutrition was expressed, but to a lesser degree, under range conditions, and that selection under better feed conditions resulted in at least as much improvement in growth rate in a range environment as selection under range conditions. There were correlated increases in birth and mature weight and decreases in ewe fertility and lamb survival in the selected lines. The decreases in ewe fertility and lamb survival were least in line HW. Total weight of lamb weaned per ewe and per ewe metabolic weight decreased for mature ewes of all selected lines. This decrease was greatest in line DW and least in line HW. The results indicate that in both drylot and range environments, single trait selection for increased body weight, although successful in increasing growth rate, did not give positive results for total weight of lambs weaned.

1098. Lasslo, Laurel L. 1982. **Direct response to selection for 120-day weight in Targhee sheep in two environments (Abstract).** J. Anim. Sci. 55(Suppl. 1):153.
***Abstract*:** Selection of 120-day weight was initiated in 1961 in two flocks from common base population of grade Targhee sheep. At Davis, sheep were maintained on a good plane of nutrition year round, on irrigated pasture or in drylot. At Hopland, they grazed annual grassland range, with supplementary feeding only at mating and lambing. Mature mating weights of base population ewes were approximately 70 and 61 kg at Davis and Hopland, respectively. Selected (DW) and control (DC) lines were maintained at Davis through 1977. At Hopland there were selected (HW) and replicate control (HC1 and HC2) lines, and a line (DH) mated to the DW selected rams, from 1961-1980. Weights were adjusted for effects of age of dam, sex and type of birth and rearing by multiplicative factors. The overall mean 120-day weights on a female, single, mature dam basis for control lines at Davis and Hopland were 33.2 and 30.4. Response or divergence was estimated as the difference between linear regression coefficients of adjusted line means on year. The Hopland replicate controls did not differ: HC1 - HC2 = -.004 ± .056 kg/yr, and the data were pooled (HC). Direct response was greater at Davis than at Hopland: DW - DC = .442 ± .086; HW - HC = .151 ± .034 kg/yr. Corresponding realized heritabilities were .16 and .08. Values for the DH line were: DH - HC = .226 ± .036; realized h^2 = .09. HW - DH = -.075 ± .037 kg/yr, indicating that 1) genetic improvement made on a higher plane of nutrition was expressed, but to a lesser degree, under range conditions, and 2) selection under better feed conditions resulted in at least as much improvement in growth rate in a range environment as selection under range conditions.


Don Holt
Research sheep on annual rangeland

1099. Lasslo, Laurel L., G. Eric Bradford, Donald T. Torell, and B. W. Kennedy. 1985. **Selection for weaning weight in Targhee sheep in two environments. I. Direct response.** J. Anim. Sci. 61(2):367-386.
Abstract: In 1961, selection for 120-day weight was initiated in two flocks from a common base population of grade Targhee sheep. At Davis, sheep were maintained on a good plane of nutrition, on irrigated pasture or in a drylot. At Hopland, sheep grazed annual grassland range, with supplementary feeding only at mating and lambing. Selected (DW) and control (DC) lines were maintained at Davis from 1961 through 1977. A selected (HW) line, replicate control (HC1 and HC2) lines, and a line (DH) mated to the Davis (DW) rams were maintained at Hopland from 1961 through 1980, with the exception that HC2 was terminated in 1977. Multiplicative factors were used to adjust weights for effects of age of dam, sex, and type of birth and rearing. Response to selection was estimated as the difference between selected and control line linear regression coefficients of adjusted line means on year. The Hopland replicate controls did not differ significantly from each other (HC1 - HC2 = .004 ± .056 kg/yr), and the control line data were pooled (HC). The overall control line mean 120-day weights on a female, single, mature-dam basis were 33.2 and 30.4 kg at Davis and Hopland,

respectively. Direct response was greater at Davis than at Hopland: DW - DC = .524 ± .073 kg/yr (P < .001); HW - HC = .151 ± .034 kg/yr (P < .001). Corresponding realized heritabilities were .17 and .06. Direct response for the DH line was DH - HC = .226 ± .036 (P < .001); realized heritability was .08. Response in the DH line was greater (P < .05) than that in the HW line: HW - DH = -.075 ± .037 kg/yr. This indicates that 1) genetic improvement made on a higher plane of nutrition was expressed, but to a lesser degree, under range conditions, and 2) selection under better feed conditions resulted in at least as much improvement in growth rate in a range environment as did selection under range conditions.

1100. Lasslo, Laurel L., G. Eric Bradford, Donald T. Torell, and B. W. Kennedy. 1985. **Selection for weaning weight in Targhee sheep in two environments. II. Correlated effects.** J. Anim. Sci. 61(2):387-397.
Abstract: Targhee sheep were selected for 120-day weight under irrigated pasture-drylot conditions at Davis (DW) and under range conditions of Hopland (HW). Unselected control lines were maintained in both environments (DC, HC1, and HC2). At Hopland, a line (DH) was maintained in which ewes were mated to Davis (DW) rams. Selection for 120-day weight was successful in both environments, with more improvement made in the drylot environment. The genetic improvement made in the dry lot environment was expressed, although to a lesser degree, under the range conditions. Correlated responses were analyzed. Birth weight increased significantly in all three selected lines; the increase was less in line DH than in the other two lines. In all selected lines, weights of ewes of all ages at mating increased significantly compared with their respective controls. Proportion of ewes lambing decreased (P < .05) in line DH; the trend was negative but nonsignificant in line DW. Differences in litter size between lines within location were not significant. Lamb survival to weaning decreased in lines DW (P < .05) and DH (P < .01), compared with their respective controls; and the trend in HW was negative but nonsignificant. Fertility and survival data indicated that, under range conditions, the line selected under drylot conditions (DH) was less fit than the line selected under range conditions (HW). As a result of the decreases in lamb survival and fertility, none of the selected lines produced more total lamb weight weaned per ewe than the controls, in spite of the significant direct response to selection. Mature ewes of line DH and DW produced less total lamb weight weaned per ewe (P < .001 and P < .05) than their respective controls. The results indicate that while single trait selection for growth rate to weaning results in heavier lambs, it does not increase and may decrease total lamb production per ewe.

1101. Li, Ma, Hakan Sakul, Martin Dally, and Eric Bradford. 1992. **Pubertal performance of Targhee ewe lambs selected for weaning weight or litter size.** SID Sheep Res. J. 8(2):54-58.
Abstract: Data were collected on 149 Targhee ewe lambs from DH and S lines (selected for weaning weight) T line (selected for multiple births), and an unselected control line (C) to study various pubertal traits. Daily observations for estrus were made using vasectomized rams. Plasma progesterone levels were monitored by weekly blood samples. A total of 98 ewe lambs showed behavioral estrus, and an additional 46 ovulated but did not show estrus. There were no significant differences in age at first behavioral estrus among lines with an overall least-squares mean of 289.4 days. Single born ewe lambs showed their first behavioral estrus about 8 d earlier than multiple born lambs (P = 0.06). Overall mean age at first apparent ovulation was 272.3 days for all ewes which ovulated, and 271.2 days for those which showed behavioral estrus. Birth date was a highly significant (P < .01) source of variation for all variables studied. Regression coefficients of ages at first behavioral estrus and first apparent ovulation on birth date were -0.72 + 0.16 and -0.65 + 0.09, respectively. Effects of line, birth type, and initial body weight on ages at first behavior estrus and first apparent ovulation were not significant. Mean interval between the 1st and the 2nd estrus was 16.9 days. Of the 79 ewe lambs which showed estrus at least 17 days after the initiation of blood sampling, 44% had one, 46% had two, and 10% had three ovulatory events prior to first detected estrus.

1102. Longhurst, William M. 1954. **The fecal pellet group deposition rate of domestic sheep.** J. Wildl. Manage. 18(3):418-419.
Abstract: On ranges where there is dual use by deer and domestic sheep, there can be difficulty in distinguishing the pellet group of these two species when utilizing the fecal pellet group count method to estimate deer populations. It was considered worthwhile to determine the pellet group deposition rate of domestic sheep so that where their numbers and duration of stay on a given range were known, a fraction of the total pellet group count could be attributed to them. Sheep on dry pasture produced 13.26 pellet groups per day (compared with 12.7 reported for deer). Two yearling ewes on green feed deposited 15 and 16 pellet groups, respectively, in 24 hours.

1103. Longhurst, William M., Norman F. Baker, Guy E. Connolly, and R. A. Fisk. 1970. **Total body water and water turnover in sheep and deer.** Am. J. Vet. Res. 31(4):673-677.
Abstract: The total body water and body water turnover in deer Columbian black-tailed deer (*Odocoileus hemionus columbianus*) and domestic sheep (*Ovis aries*) were compared in winter and summer by testing with tritium oxide. There was significant difference in water turnover in both species when data obtained in the winter were compared with those obtained in the summer. In addition, there was significant difference in water turnover between the two species in both winter and summer. Deer had a larger body water pool in relation to body weight than did sheep, but the rate of body water turnover in deer was slower in both winter and summer. The mean body water pools of sheep in winter and in summer were 53.3% and 46.0% of body weight, respectively. Comparable values for deer were 63.4% and 73.5%. The water flux in sheep was 0.102 and 0.140 L/kg/day in winter and in summer, respectively. Comparable values in deer were 0.053 and 0.104 L/kg/day.

1104. Luick, J. R., Donald T. Torell, and W. Siri. 1959. **A method for the determination of water intake of grazing sheep.** Int. J. Appl. Radiation and Isotopes 4:169-172.
Abstract: A method is described by which the moisture content of grazed pastures may be calculated. Sheep, fitted earlier with esophageal fistulas, were dosed with tritiated water. The saliva water, which had been added to the egesta, was calculated by the isotope dilution technique. Forage water was then calculated as the difference between total water in the egesta and saliva water. The validity of this method was verified by feeding ewes a ration of known water content. The results obtained by the isotope dilution technique and by dehydration were in close agreement. This method may be especially useful on ranges where it is impossible to obtain representative samples of grazed forage.

1105. Markowitz, Tim M., Martin R. Dally, Karin Gursky, and Edward O. Price. 1998. **Early handling increases lamb affinity for humans.** Anim. Behaviour 55(3):573-587.
Abstract: Domestic animals that are socialized to humans are often more easily managed and less timid than those that are not. We examined whether increased handling and artificial feeding of domestic sheep, *Ovis aries*, at an early age would decrease their subsequent timidity towards people. Forty-eight lamb twin sets were divided into four treatment groups for 2 days of treatment at ages 1-3, 3-5, 5-7, or 7-9 days. Treatment lambs were fed milk replacer and were handled four times/day for 5-min periods. Their twins, used as controls, were left with their dams. Two 5-min tests of lamb temperament were conducted at ages 2, 4, 6, 8, 10, 15, and 25 days.

Testing consisted of a stationary human encounter, in which lambs' responses to a sitting person were recorded continuously, and a moving human encounter, in which lambs' responses to a person walking at 0.5 m/2 s were recorded by instantaneous scans. Measures included latency to proximity (<2 m) and arm's reach (<1 m) of the person, time spent in proximity and within arm's reach, average distance (m), mean number of human contacts, number of lambs contacting a person, and following/approach/avoidance. Treatment lambs showed significantly greater affinity for humans than their twin controls. The 1-3-day treatment group showed the greatest response to treatment, consistently outperforming controls in all of the above measures. These results suggest that 40 min of positive human contact at age 1-3 days reduces lamb timidity to people. Socialization of lambs to humans need not disrupt the primary lamb-dam bond, and it may have positive management as well as welfare implications.

Animal Science interns (left to right) Alisa Boswell, Kathy Hill, Rachel Smith, and Kevin Keegan help process lambs, Winter 1980

1106. Marshall, B., Donald T. Torell, and R. M. Bredon. 1967. **Comparison of tropical forages of known composition with samples of these forages collected by esophageal fistulated animals.** J. Range Manage. 20(5):310-313.
Abstract: Most previous studies with esophageal fistulas have been conducted in the temperate zone with sheep and British-type cattle. The principal breed of cattle in Uganda is the Zebu, which has been indigenous for several centuries. Since saliva is the major contaminant in all esophageal fistula collections, its effect on tropical forage consumed by Zebu cattle was studied. As most field sampling was done at sites distant from laboratory facilities, it was necessary to develop a method of sample preservation suitable for field use. In these studies, it was found that the effect of saliva on esophageal fistula samples was minimal. Regression equations are presented which compare crude protein and crude fiber contents of esophageal fistula samples with those of forage of known composition. Squeezing esophageal fistula samples, air drying the solid protein, and treating the liquid portion with phenol was found to preserve samples where laboratory facilities are not available.

1107. Martin, N. L., Edward O. Price, S. J. R. Wallach, and M. R. Dally. 1987. **Fostering lambs by odor transfer: the add-on experiment.** J. Anim. Sci. 64:1378-1383.
Abstract: Lamb specific odor is used by ewes to discriminate between their own and alien offspring. Recent studies have demonstrated that fostering can be facilitated by transferring own-lamb odor to alien lambs in cloth stockinettes. The objective of the present study was to investigate the effectiveness of the odor transfer technique in enticing ewes with a single lamb to adopt an additional lamb ("add on" procedure). Shortly after birth, nylon stockinettes were placed on the single offspring of 49 ewes and 49 additional alien lambs designated for fostering. Approximately 20 hours following parturition, stockinettes were removed from 41 natural lambs and placed on alien lambs (experimental treatment). In the control treatment (8 ewes), own and alien lambs retained their own stockinettes. Four acceptance tests were conducted, 24 hours apart, starting at the onset of fostering. Successful adoptions were attained for 21 of 31 experimental ewes (68%) exposed to add-on lambs similar in facial coloration to their own lambs. Only 2 of 10 experimental ewes (20%) with whiteface natural lambs adopted blackface add-on lambs. One of the eight control ewes (12.5%) adopted an add-on lamb. Of the 24 ewes that adopted alien lambs, 10 (41.7%) demonstrated immediate acceptance and 20 (83.3%) had adopted lambs by the second test day. A higher proportion of primiparous than multiparous ewes adopted alien lambs. The presence of own-lamb odor on stockinettes worn by add-on lambs appears to facilitate fostering. However, the presence of own-lamb odor may not be a significant enough cue to override obvious differences in facial coloration between own and add-on lambs. Lamb specific odor transfer is an effective and efficient method for managing ewes to rear additional lambs.

1108. McClelland, Robyn G. 1985. **Comparative energy expenditure of sheep and goats under range conditions.** M.S. Thesis, Univ. Calif. Davis. 57 pp.
Abstract: Six Suffolk-cross sheep and six Angora goats aged between one and two years were used to compare energy expenditure of sheep and goats under different range conditions. Three trials were run. In Trial 1, animals were held in metabolism cages and fed a maintenance diet of 55.3g alfalfa/$kg^{0.75}$/day. Sheep and goats were run on brush in Trial 2 and on pasture in Trial 3. Energy expenditure of sheep and goats in Trial 2 (668.01 and 1978.43 kJ/kg/day, respectively) was significantly higher than in Trials 1 and 3 (187.17, 161.28 Trial 1; 403.21, 488.55 Trial 3) ($P < 0.5$), and energy expenditure of goats was significantly higher than sheep in Trial 2 ($P < .0001$). No significant differences were found between goats and sheep in Trials 1 and 3. It was concluded that the difference in energy expenditure between sheep and goats in Trial 1 could not be attributed just to differences in grazing behavior, as climate confounded the results. The study did show that under favorable climatic and pastoral conditions, no difference in energy expenditure existed between sheep and goats.

1109. Medrano, J. F., and G. Eric Bradford. 1991. **Growth performance and plasma insulin-like growth factor I concentrations in sheep selected for high weaning weight.** J. Anim. Sci. 69:1912-1918.
Abstract: A study was undertaken to determine the effect of selection for high weaning weight on concentrations of plasma insulin-like growth factor I (IGF-I) in sheep and to evaluate the usefulness of measuring IGF-I as an aid in identification of genotypes with a higher growth potential. Lambs from two lines selected for high 120-day weight (HW and DH) and an unselected control (C) were weighed and blood samples collected monthly from birth to weaning (4 months of age). A clear differentiation in size occurred after 1 month of age between lines, between sexes, and between singles and twins. At weaning, selected lines were 3.8 and 5.0 kg heavier than controls. Plasma IGF-I concentrations were 1.5 to 2 times higher ($P < .001$) in males than in females after 1 month of age. There were no significant differences in IGF-I concentration between lines or types of birth. However, line DH and single lambs on average had higher concentrations of IGF-I. Within sex and type of birth, correlations between IGF-I concentrations at 0, 1 ,2, 3, and 4 months and 4-month BW ranged from -.16 to .49 in the three lines, and most were not significant. Coefficients of variation for IGF-I concentrations (36 to 50%) were two to three times higher than those for BW (11 to 15%). Due to high variability of IGF-I measurements,

the low correlations between IGF-I concentrations and BW, and the small differences in IGF-I between control and selected lines, measurement of plasma IGF-I is unlikely to be an effective aid to selection for growth rate in sheep.

1110. Near, Jean. 1992. **Marketing wool to handspinners.** Pp. 45-50 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The author discusses her personal experiences of direct marketing fleeces to handspinners. Comments about sheep breeds used, feed purchase and feeding, and flock management are included. She describes her main marketing success, a one-day "shear-in" to which handspinners are invited on the day her flock is sheared. Sources of useful information and materials are listed.

1111. Nebesar, Charles V. 1967. **Maternal transfer and fetal absorption and retention of injected radionuclides in deer and sheep.** M.S. Thesis, Univ. Calif. Davis. 44 pp.
Abstract: Placental transfer and fetal retention of calcium-47, cesium-137, strontium-85, and iodine-131 were studied. Deer and sheep fetuses accumulated almost comparable concentrations of the injected radionuclides. The amount of radionuclide transported across the placenta and deposited in the fetus was dependent upon the mass of the total conceptus. The physiological demands of the rapidly growing fetal bone influenced the amount of radiostrontium and radiocalcium crossing the placenta. There was discrimination against radiostrontium by the placenta. A slight increase in the OR with time of gestation was noted. Urinary discrimination was demonstrated, radiostrontium being excreted more rapidly than radiocalcium. Mammary discrimination against radiostrontium was observed in the deer. There was a rather large radionuclide accumulation in the upper gastrointestinal tract (rumen-reticulum, omasum, and abomasum, and contents) after intravenous injection, presumably due to parotid gland secretion. The only significant deposition of radiocesium occurred in maternal muscle (gluteal and diaphragm) with a very slight accumulation in fetal soft tissue. There was low uptake of radioiodine by the maternal thyroid glands of the deer, probably because of the apparent high stable iodine content of the diet. In the deer, there was greater accumulation of radioiodine in the fetal thyroid glands than in the maternal thyroid glands. No significant species differences between maternal and fetal tissues were demonstrated in deer and sheep following intravenous injection of the radionuclides of calcium, cesium, strontium, and iodine.

1112. Nelson, Aaron O. 1987. **Ewe lamb breeding... a check you're not cashing?** Pp. 37-40 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Many California producers are not utilizing one of their valuable resources, their ewe lamb flock. They offer the potential of extra lambs now, plus higher reproductive performance throughout their lifetime. There are costs to pay before this potential can be realized, but for each cost there is a return. Knowing the characteristics of successful lamb breeding programs, and dedicated application of basic practices to one's operation, can provide real rewards. Criteria and guidelines for establishing such a program, as well as helpful hints and suggestions, are provided.

1113. Oh, Hi Kon, T. Sakai, Milton B. Jones, and William M. Longhurst. 1967. **Effect of various essential oils isolated from Douglas fir needles upon sheep and deer rumen microbial activity.** Appl. Microbiol. 15(4):777-784.
Abstract: The effects of essential oils from Douglas fir needles on sheep and deer rumen microbial activity were tested by use of an anaerobic manometric technique. Rumen microorganisms were obtained from a sheep which had been fed mainly on alfalfa hay and dried range grass. One deer used in this study had access to Douglas fir trees the year around, whereas the other deer had no access to Douglas fir. All of the monoterpene hydrocarbons isolated from Douglas fir needles– α-pinene, ß-pinene, limonene, myrcene, camphene, Δ^3-carene, and terpinolene– promoted only slightly or had no effect on deer rumen microbial activity, whereas all of them promoted activity in sheep rumen microbes, except Δ^3-carene and terpinolene, which inhibited activity. Of the oxygenated monoterpenes, all monoterpene alcohols– α-terpineol, terpinen-4-ol, linalool, citronellol, and fenchyl alcohol– strongly inhibited the rumen microbial activity of both sheep and deer. Monoterpene esters (bornyl acetate) produced mild inhibition for both sheep and deer microbes, and citronellyl acetate inhibited microbial activity in sheep, whereas it promoted activity in both deer. Monoterpene aldehyde (citronellal) inhibited the activity of rumen microbes from both sheep and deer having no access to Douglas fir from the Hopland Field Station, whereas they produced no effect upon deer having access to Douglas fir from the Masonite forest. Rumen microbial activity for sheep and deer was promoted slightly with aliphatic ester (ethyl-*n*-caproate). There was a marked difference between sheep and deer rumen microbes as affected by addition of the various essential oils. The monoterpene hydrocarbons promoted activity more on sheep rumen microbes than on deer, and the monoterpene alcohols inhibited sheep rumen microbial activity more than that of deer. Furthermore, the deer rumen microbes from Hopland Field Station, where Douglas fir is absent, were affected more than the deer from Masonite forest.

1114. Oh, Hi Kon, Milton B. Jones, and William M. Longhurst. 1968. **Comparison of rumen microbial inhibition resulting from various essential oils isolated from relatively unpalatable plant species.** Appl. Microbiol. 16(1):39-44.
Abstract: Essential oils were isolated from eight plant species which were relatively unpalatable to deer and sheep. The inhibitory potency of these oils upon rumen microorganisms was compared, in terms of total gas and volatile fatty acid (VFA) production, by use of an anaerobic manometric technique. Inhibitory effects of oils from the eight plant species may be placed in four groups: (i) essential oils from vinegar weed (*Trichostema lanceolatum*) and California bay (*Umbellularia californica*) inhibited rumen microbial activity most; (ii) lesser inhibition was exhibited by rosemary (*Rosmarinus officinalis*) and California mugwort (*Artemisia douglasiana*) oils, followed by (iii) blue-gum eucalyptus (*Eucalyptus globulus*) and sagebrush (*Artemisia tridentata*) oils; and (iv) oils from Douglas fir (*Pseudotsuga menziesii*) and Jerusalem oak (*Chenopodium botrys*) resulted in the least inhibition, when 0.3 ml of each oil was used. A highly significant correlation ($r = 0.98$**) between total gas and VFA production indicated the validity of either method to measure the activity of rumen microorganisms. Our results are discussed in relation to the hypothesis that the selectivity and voluntary consumption of ruminants are related to the characteristic odor and antibacterial action of essential oils isolated from relatively unpalatable plant species.

1115. Oh, Hi Kon, William M. Longhurst, and Milton B. Jones. 1969. **Relation of nitrogen intake to rumen microbial activity and consumption of low-quality roughage by sheep.** J. Anim. Sci. 28(2):272-278.
Abstract: The activity of rumen microorganisms in relation to consumption of low-quality range grasses by sheep with and without supplementation was evaluated in terms of gas and VFA production. Low-quality range forage was supplemented with urea alone, urea plus VFA, urea plus caproic acid, and casein alone. All supplements increased voluntary feed consumption, microbial activity, dry matter digestibility, concentration of rumen VFA and microbial protein and blood urea levels, but not blood glucose. However, none of the supplements enhanced these parameters significantly above the levels produced by urea alone. This indicated that rumen microorganisms appear to be capable of synthesizing their essential cellular components utilizing urea alone as a source of nitrogen. Reduction

of intake on the control diet of unsupplemented range grass was considered to result from the nitrogen deficiency in this ration with consequent lowering of bacterial activity. However, progressive increases in consumption during treatment periods reflect increased microbial activity. After the first series of trials, microbial activity and consumption continued to increase progressively in apparent response to the carry over effects of enhanced nitrogen supplementation.

1116. Oh, John H., Donald T. Torell, William C. Weir, and William M. Longhurst. 1970. **Development of microbial activity in the alimentary tract of young rams (Abstract).** Abstracts, 62nd Ann. Mtng., Am. Soc. Anim. Sci. 31:250.
Abstract: Microbial fermentation activities in the various parts of the alimentary tracts of lambs, 1, 7, 14, 21, 28, 55, and 75 days of age were studied in terms of VFA levels and fermentation gas production in anaerobic Warburg apparatus. Caecal VFA concentrations exceeded ruminoreticular levels in lambs from 1 through 28 days of age, while the reverse was true in older lambs. Total VFA concentrations in the hindgut (including caecum and anterior colon) also exceeded those in the ruminoreticulum in lambs through 21 days of age. The fermentation capacity of the caecum in lambs through 21 days likewise was significantly higher than that of the ruminoreticulum. It is concluded that significant hindgut fermentation precedes the development of rumen microbial activity.

1117. Oh, John H., William C. Weir, and William M. Longhurst. 1971. **Feed value for sheep of cornstalks, rice straw and barley straw as compared with alfalfa.** J. Anim. Sci. 32(2):343-347.
Abstract: Low quality roughages represent a large potential source of feed energy if they can be utilized through ruminants. Crop residues such as the cereal straws currently contribute little to livestock feeding an their disposal by burning contributes to the problem of air pollution. The enrichment of straw with added nutrients such as nitrogen in the form of urea, branched volatile fatty acids, sulfur, and other minerals has demonstrated that increased feed intake and improved digestibility is possible with such low quality roughages serving as the primary source of energy. The trial reported here was an attempt to improve the feeding value of cornstalks, rice straw, and barley straw by adding nitrogen, phosphorus, and sulfur to the pelleted roughages. The feed values of pelleted cornstalks, rice straw and barley straw fortified to equivalent N, P and S levels and unsupplemented pelleted alfalfa were compared in digestion trials with rumen fistulated sheep. Dry matter intake and digestibility, digestible energy, rumen fermentation, and ruminal VFA and microbial protein data indicated that the relative feed value of these rations was from highest to lowest, alfalfa, cornstalks, rice straw and barley straw. The results indicate that fortified cornstalks and rice straw can be used as a part or all of the maintenance ration of sheep.

1118. Oh, John H., I. D. Hume, and Donald T. Torell. 1972. **Development of microbial activity in the alimentary tract of lambs.** J. Anim. Sci. 35(2):450-459.
Abstract: Two experiments were conducted to study the development of microbial fermentation in the various parts of the alimentary tract of lambs. The first experiment was concerned with the period from birth to 75 days of age. The second experiment was concerned with the development of fermentation activity between 56 and 150 days of age as it may be affected by diet. The effects of diet after 56 days of age on the anatomical development of the digestive tract were minor, but lambs fed in drylot had higher concentrations of volatile fatty acid (VFA) in their ingesta than lambs on pasture, and grew faster. The development of a functional rumen was preceded in the first 3 to 4 weeks of age by a period of significant hindgut fermentation. However, it was calculated that the VFA so produced made only a small contribution to the energy metabolism of the lamb (4.1% of the intake of digestible energy). VFA production in the ruminoreticulum of these lambs was equivalent to only 2.4% of the digestible energy intake.

A. H. Murphy

Dr. John Oh and Lee U. Oh process rumen samples in HFS laboratory, 1969

1119. Osman, Ahmed H., and G. Eric Bradford. 1965. **Effects of environment on phenotypic and genetic variation in sheep.** J. Anim. Sci. 24(3):766-774.
Abstract: Livestock populations frequently occur in a wide variety of environments to which they have been well adapted through artificial and natural selection. Consequently, there is much variability on both phenotypic and genotypic levels between and within populations and subpopulations. In order to exploit fully this variability through selective breeding, a problem of practical importance must be resolved: can the best response to selection be achieved when selection is carried out under less than optimal conditions, or when it is carried out in an environment that is especially favorable for the expression of the desired character? This work is an attempt to answer the questions: 1) does phenotypic or genetic variation vary between environments differing mainly in plane of nutrition, 2) is there an interaction between genotype and environment, and 3) what is the optimum environment for selection? Five years' data on an experiment conducted at two locations (Hopland and Davis) using whiteface Targhee-type sheep were used to study genotype-environment interaction and the effects of environment on phenotypic and genetic variation. The traits studied included birth and 120-day weights, gain from weaning to Fall and from Fall to shearing, 450-day weights, grease fleece weight, staple length, fleece grade, conformation score, and face score. The results indicate that for most traits, including the trait under selection (120-day weight), the phenotypic variance is higher in the "good" than in the "poor" environment, with the result that the selection differentials are also higher for the former. The higher variance is not explained by higher means, since it was found for traits for which the means did not differ. Even though the average paternal half-sib heritability estimates for both 120-day weight and yearling traits are higher in the better environment, the realized heritability estimates for 120-day weight from the response to 3 years of selection are not. There was no evidence of large genotype-environment interactions. Estimates of genetic correlations indicate that the only characteristics likely to be affected by selection for 120-day weight are 450-day weight and conformation score. Both will be affected favorably. No important genetic correlations were found between 120-day weight and fleece traits.

1120. Osman, Ahmed H., and G. Eric Bradford. 1967. **Genotype-environment interaction and compensatory growth in sheep.** J.

Anim. Sci. 26(6):1239-1243.
Abstract: Feedlot performance is an economically important trait in meat animals. Genotype-environment interaction and compensatory growth are potentially complicating factors which may make the job of selecting animals for such performance more difficult. This study was undertaken to obtain information on these two phenomena from a lamb feeding trial. Forty individually-fed ram lambs and 78 group-fed wethers were used to study genotype-environment interaction in post-weaning gain, body measurements, wool, and carcass data. The rams and wethers were the progeny of 5 and 8 sires, respectively. Each sire family was divided at random into two groups, one of which was put on poor ration and the other on a good ration for 7 weeks. Subsequently, all animals were fed the good ration for another 7-week period. Significant sire by plane of nutrition interaction was found in only 5 of 38 comparisons, suggesting that this interaction is not a major source of variation even when the nutritional treatment effect is large. Compensatory growth was made by both restricted groups, but there were no sire differences in compensatory growth.


Don Torell

Superintendent Al Murphy (far left) and assistant shepherd Richard Rainoldi (holding ewe) pose with Petaluma FFA students and their instructor Bill King (far right), February 1968

1121. Pope, R. E. 1992. **Wool Quality Improvement Program – an evaluation.** Pp. 51-63 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The American Sheep Industry Association's (ASI) "Wool Quality Improvement Program" (WQIP) is discussed as it pertains to raw wool preparation and marketing. This history of this program and its predecessor, the "Pack It With Pride" program, are summarized. Certification of wool classers, combing trials, marketing data, and sale quantities and prices are given for 1990 and 1991. The continued ability to improve U.S. wool sales by objective measures will make U.S. wools more competitive.

1122. Price, Edward O., Gerald Dunn, Jennifer Talbot, and Martin Dally. 1983. **Fostering lambs by odor transfer.** Calif. Sheepman's Quarterly 58(Jul-Aug):35-36.
Abstract: *see* Price et al. 1983. National Wool Grower 73:5-6.

1123. Price, Edward O., Gerald Dunn, Jennifer Talbot, and Martin Dally. 1983. **New "jackets" eases fostering.** Natl. Wool Grower 73:5-6.
Abstract: It is well known that ewes can recognize their young by odor, visual appearance, or characteristic vocalizations. However, final discrimination between one (natural) and alien young is ultimately based on smell. Ewes are reluctant to accept and care for alien lambs because of their innate predisposition to mother only those young that smell like their own offspring. The lambs of 46 Targhee-type ewes housed at the Hopland Field Station were fitted with nylon "Stretchtex" orthopedic stockinettes within three hours of birth. Stockinettes covered the back of the head, neck, body, and much of the tail. Lambs wore their stockinettes for about 48 hours before transferring them to aliens. Thirty-five of the 40 alien lambs (88%) that received transferred stockinettes were successfully adopted. All 6 alien lambs that retained their own stockinettes were rejected. Of the 26 ewes that adopted aliens and were given acceptance tests, 10 (38%) accepted their foster young immediately and 22 (85%) had begun to exhibit acceptance behavior by 36 hours after fostering. In conclusion, odor transfer represents a relatively rapid, safe, and inexpensive way to substitute alien lambs for natural lambs. Future research will determine the feasibility of using odor transfer to foster a second lamb on single-bearing ewes with a good milk supply.

1124. Price, Edward O., Margaret Dunbar, and Martin R. Dally. 1984. **Behavior of ewes and lambs subjected to restraint fostering.** J. Anim. Sci. 58(5):1084-1089.
Abstract: The objective of this study was to investigate the development of maternal-filial social attachments between ewes and alien lambs using the technique of "restraint fostering." Forty-eight to 72 hours after parturition, 22 Targhee-type ewes were separated from their natural lambs, placed in restraining devices (stanchions), and each exposed to a single alien lamb. After a period of 1 or 4 days of restraint, the ewes were subjected to five 10-minute lamb acceptance tests over a 48-hour period. The observer recorded butts and butt attempts by the ewe and successful and unsuccessful suckle attempts by the lamb. The ewe-lamb pairs were then housed in pens with other groups of ewes and lambs and observed intermittently for acceptance behaviors. Six of the 14 ewes restrained for 4 days and non of the eight ewes restrained for 24 hours met the criterion for successful adoption within 48 hours. After being housed in group pens, adoptions were achieved by three ewes in the 1-day group and an additional four ewes in the group restrained for 4 days. Ewes restrained for 24 hours were significantly more aggressive toward fostered young than ewes restrained for 4 days. In addition, the proportion of successful suckling attempts was significantly lower for lambs fostered on ewes in the 1-day group. Both groups showed a decline in butts and butt attempts over successive acceptance tests, but while the proportion of successful suckling attempts declined for lambs housed with 1-day ewes, they increased over time for lambs fostered on ewes restrained for 4 days. Vocalization frequencies of ewes when separated from their natural lambs could not be used to predict fostering success. The average weaning weight of fostered lambs was well within the normal range for naturally reared lambs at the same location. It was concluded that fostering initiated 2 to 3 days after parturition is successful in the majority of cases if the ewe is restrained in a pen with the alien lamb for 4 or more days, followed by a period of unrestrained cohabitation as a pair and subsequent exposure to groups of females with young.

1125. Price, Edward O., Gerald C. Dunn, Jennifer A. Talbot, and Martin R. Dally. 1984. **Fostering lambs by odor transfer: the substitution experiment.** J. Anim. Sci. 59(2):301-307.
Abstract: Lamb-specific odor is used by ewes to discriminate between their own and alien offspring. The objective of the present study was to investigate the feasibility of transferring own-lamb odor to alien young to facilitate fostering. Shortly after birth, cloth stockinettes (body suits) were placed on the offspring of 37 multiparous ewes. At 48 to 72 hours after parturition, a lamb from each ewe was replaced by an alien lamb. In 31 cases the odor-impregnated stockinette of the ewe's own lamb was placed on the alien lamb; in the remaining 6 cases the alien lamb retained its own stockinette (control condition). Lamb acceptance tests were

conducted every 12 hours for two days after fostering and once daily for the following two days. Twenty-six of the 31 experimental ewes (84%) adopted alien lambs using the odor-transfer technique. All of the control lambs were rejected. Of the twenty-six ewes that adopted foster young, 10 (38%) showed immediate acceptance and 22 (85%) were exhibiting acceptance behaviors by 36 hours after fostering. There were no significant differences in the fostering success of ewes bearing single lambs and those with twins. The presence of own-lamb odor rather than the absence of alien lamb odor appears to be the salient cue for lamb acceptance. Lamb-specific odor transfer represents a relatively inexpensive and rapid technique to achieve maternal acceptance of alien lambs by postpartum ewes.


Martin R. Dally

Lamb with stockinette, used in odor-transfer fostering studies, January 1987

1126. Price, Edward O., Nancy L. Martin, Gerald C. Dunn, Martin R. Dally, Fremont L. Bell, and Margaret Sublette. 1986. **Fostering lambs by odor transfer.** Calif. Agric. 40(9-10):4-5.
Abstract: Orphaned lambs present difficulties to sheep producers. It is often not profitable to rear "extra" lambs artificially (with milk replacer), and post-partum ewes are reluctant to accept any lambs other than their own. Lambs are sometime orphaned by the death of their mother, but more frequently they are rejected by the ewe or are taken away by the shepherd because of the mother's inadequate milk supply. Additionally, ewes sometime become separated from their lambs when lambing occurs on pasture. In the future, there are likely to be more extra lambs as improved breeding and management techniques increase the proportion of multiple births. The solution to this problem seems obvious, since many ewes give birth to single lambs but have the potential to raise twins. The question is how to entice these ewes to adopt extra lambs. Ewes initially learn to identify their own young by odor, sensed immediately after birth as the ewe licks and grooms her lamb. Since own-lamb odor facilitates maternal behavior, in theory an alien lamb should be more attractive to a foster mother if it carries the odor of her own lamb. Shepherds have used this concept for centuries by skin-grafting, i.e. removing the pelt of a dead lamb and placing it on the lamb to be fostered like an overcoat. This study used a technique that does not require a dead lamb. Instead, a cloth jacket or "stockinette" worn for a time by a ewe's own lamb acquires "own lamb" odor. When subsequently transferred to an alien lamb, it should smell enough like the ewe's own lamb to cause acceptance. Using 4-inch diameter Stretchtex nylon orthopedic stockinettes, we gave own-lamb odor to alien lambs and substituted them for own lambs, achieving a 91% acceptance in ewes that had given birth to single lambs and a 90% acceptance in ewes that had given birth to twins. All of the control ewes rejected alien lambs. In a second experiment, 39 ewes with single lambs were given a second lamb ("add-on" procedure). We fitted own and alien lambs with stockinettes within a few hours of birth. In this case, 21 ewes (68%) adopted alien young. A third experiment investigated add-on fostering when own and alien lambs had different facial coloration (white vs. black); only 2 of 10 ewes (20%) accepted an alien lamb of different facial coloration than their own lamb. This result demonstrates that ewes can use distinguishing visual cues, when available, to discriminate among lambs. Add-on fostering is more difficult to achieve than substitution fostering, because own-lambs are present as a reference for comparing odors or visual characteristics. In add-on fostering, it is necessary to confuse the ewe as to which lamb is her own. In general, fostering attempts are most successful if they are begun as soon as possible after birth. The fostered lamb must remain vigorous. Until adoption occurs (usually within 24-36 hours), it may be necessary to restrain the ewe a couple of times daily to allow the fostered lamb to suckle. First-time mothers more readily accept alien lambs than do experienced ewes. Stockinettes may be removed from adopted lambs 48 hours after acceptance occurs.

1127. Price, Edward O. 1987. **Ram sexual behavior.** Pp. 29-32 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: Variation in sexual performance of rams may be far less evident to producers with natural-breeding programs than to producers who "hand-breed" ewes. Poor ram performance can result in a large proportion of "open" ewes and/or lambs born late in the season. Physical examinations of rams can identify only about a third of poor-performing individuals; the rest must be identified by behavioral observation. Factors that account for variation in mating competence are discussed, including genetics, rearing experience, social dominance, and mate preference. Serving capacity tests are described and recommended as a means of predicting ram sexual performance.

1128. Price, Edward O., Nancy L. Martin, Gerald C. Dunn, Martin R. Dally, Fremont L. Bell, and Margaret Sublette. 1987. **Fostering lambs by odor transfer.** SID Res. Digest 3(2):29-32.
Abstract: *see* Price et al. 1986. Calif. Agric. 40(9-10):4-5.

1129. Price, Edward O., D. Q. Estep, Samoa J. R. Wallach, and Martin R. Dally. 1991. **Sexual performance of rams as determined by maturation and sexual experience.** J. Anim. Sci. 69:1047-1052.
Abstract: Many sheep producers are reluctant to use ram lambs in their breeding programs, even though a relatively high percentage of males achieve mating (ejaculatory) competence by 7 months of age. For many producers, concerns about small body size, physical condition, and sexual experience outweigh the economic benefits and accelerated genetic improvement provided by using rams for breeding in their first year of life. The purpose of this study was to compare the sexual performance of rams that differed in age (maturation) and sexual experience. Twenty-four ram lambs (8 mo of age) and 21 rams (20 mo of age) were individually exposed to four females in hormonally induced estrus for 30 min on five occasions, 7 days apart. Half (12) of the ram lambs and nine of the yearlings were sexually naive at the start of testing (had been denied access to females since weaning); the remaining males were sexually experienced. The sexual performance of the virgin rams was poorer during the initial exposure to females during subsequent tests, whereas sexual behavior of the sexually experienced males did not change over the days of testing. Sexually naive ram lambs and rams exhibited an improvement in sexual performance between Tests 1 and 2; during Tests 3 to 5 the sexual performance (ejaculations per test) of sexually naive and experienced rams was similar. The only effects of age (maturation) on sexual performance during the last three days were a higher frequency of mounts without ejaculation plus mount attempts ($P < .03$) and a greater number of mount interactions per ejaculation ($P < .02$) by ram lambs. In conclusion, one or two relatively brief exposures to estrous females can bring the

sexual performance of virgin rams up to levels comparable to that of experienced males. Also, ram lambs in good condition exhibit acceptable levels of sexual performance.

1130. Price, Edward O., Samoa J. R. Wallach, and Martin R. Dally. 1991. **Effects of sexual stimulation on the sexual performance of rams.** Appl. Anim. Behav. Sci. 30:333-340.
Abstract: The sexual performance of bulls and male goats is improved if they are allowed to view heterosexual behavior of other males as a prelude to mating. The purpose of the following study is to determine whether sexual stimulation enhances the sexual performance of rams. In Experiment 1, 11 sexually experienced ram lambs (~ 9 months of age) and 18 sexually experienced yearling and 2-year-old rams were individually exposed to 4 unrestrained, hormone-induced estrous females for 60 minutes after viewing the courtship and mounting behaviors of a male conspecific for 20 minutes (two tests) and in the absence of stimulator animals (two tests). In contrast to the results with bulls and bucks, the rams were hardly influenced by the sexual stimulation treatment. Latencies for the first mount and first ejaculation were shorter for sexually stimulated ram lambs; otherwise, treatment differences were negligible. A similar follow-up experiment was administered to 12 mature rams using restrained females in the sexual performance tests. Again, treatment differences were minor. It was concluded that sexual stimulation does not functionally enhance the sexual performance of rams. Species differences in response to sexual stimulation are discussed in terms of female sexual behaviors that may result in a selective (competitive) advantage to males that are stimulated to locate and mate with females early in the estrous period.

1131. Price, Edward O., Hans W. Erhard, Reid Borgwardt, and Martin R. Dally. 1992. **Measures of libido and their relation to serving capacity in the ram.** J. Anim. Sci. 70:3376-3380.
***Abstract*:** The purpose of this study was to determine whether ejaculation rate (serving capacity) of sexually experienced rams could be estimated by selected measures of sexual libido when rams were exposed to estrous ewes under conditions that prevented copulations. Twenty-four crossbred rams selected for either high or low rates of copulation were exposed to two restrained estrous ewes under three treatment conditions that 1) permitted the full range of precopulatory and copulatory behaviors, 2) permitted precopulatory behaviors and mounting but precluded copulation, or 3) permitted precopulatory behaviors but not mounting or copulation. Frequencies of precopulatory behaviors (bouts of leg-kicking and anogenital sniffing) in each of the three treatment conditions and mounting frequency in Treatment 2 occurred in proportion to the ram's characteristic ejaculation rate ($P < .001$), suggesting that the mating potential of rams can be estimated under conditions that preclude copulation. Frequencies of precopulatory behaviors and mounting were lower when rams were allowed to copulate, due largely to periods of sexual inactivity after ejaculations.

1132. Price, Edward O., Reid Borgwardt, and Martin R. Dally. 1993. **Effect of ewe restraint on the libido and serving capacity of rams.** Appl. Anim. Behav. Sci. 35:339-345.
Abstract: The study examines the effect of ewe restraint when assessing the libido and serving capacity of rams. Twenty-five domestic rams were exposed to both unrestrained and restrained estrous ewes under circumstances in which copulations were permitted and prevented. Ewe restraint did not affect the rate of ejaculation or measures of precopulatory behavior when copulation was permitted. When rams were exposed to ewes whose perinea had been covered to prevent copulations (libido tests), bouts of leg-kicking and anogenital sniffing were not affected by female restraint but mounting occurred more frequently when ewes were unrestrained. The latter measures of libido correlated with ejaculation rates (serving capacity) observed in tests permitting copulation and, in 4 out of 6 cases, were slightly higher when covered females were restrained. Rams were particularly aggressive (butts and vigorous pawing) toward ewes that were covered and restrained. It was concluded that the advantages of ewe restraint are not great enough to justify its use when assessing the libido and mating potential of rams with estrous ewes.

1133. Price, Edward O., Judith K. Blackshaw, Alan Blackshaw, Reid Borgwardt, Martin R. Dally, and Robert H. BonDurant. 1994. **Sexual responses of rams to ovariectomized and intact estrous ewes.** Appl. Anim. Behav. Sci. 42:67-71.
Abstract: This investigation compares the sexual performance of rams when exposed to ovariectomized and intact estrous ewes. In Experiment 1, 22 sexually experienced rams were sequentially exposed to hormone-induced ovariectomized estrous ewes or intact estrous ewes that were cycling naturally or induced to exhibit estrus using progestin sponges. The sexual performance of the rams was not affected by ewe treatment. In Experiment 2, 95 rams were simultaneously exposed to ovariectomized and intact ewes induced to exhibit estrus via hormone treatment. Rams mounted ovariectomized ewes more frequently than intact females, but ejaculation rates were similar for the two treatments. It was concluded that the ejaculation frequency of rams in sexual performance tests (i.e. serving capacity) is not biased by the mode of estrus induction of the stimulus females.

1134. Price, Edward O., Reid Borgwardt, Judith K. Blackshaw, Alan Blackshaw, Martin R. Dally, and Hans Erhard. 1994. **Effect of early experience on the sexual performance of yearling rams.** Appl. Anim. Behav. Sci. 42:41-48.
Abstract: The study examines the effect of early sexual experience on the sexual performance of yearling rams. Forty-eight rams were given four individual 30-min exposures to estrous ewes at 10 months of age (experimental Ss). Forty-seven male counterparts were given no early heterosexual experience (control Ss). All subjects were maintained in a single all-male group from weaning (3 months of age). At 22 months of age, experienced and control rams were individually exposed to four estrous ewes for 30 min on four occasions at weekly intervals. Sexual behaviors observed included courtship, mounting, and ejaculation frequencies. Significantly fewer experienced rams than control rams ($P < 0.01$) failed to show sexual interest in ewes on Test Day 1 (1 of 48 vs. 13 of 47 rams, respectively). In addition, sexually active experienced rams exhibited higher ($P < 0.01$) rates of ejaculation than sexually active control rams on all four test days ($\bar{x}$ = 4.17 vs. 3.45 per 30 mins, respectively). Follow-up studies on non-performing rams revealed that continuous exposure to ewes usually activated sexual interest in females. It was concluded that lack of exposure to ewes during early development can inhibit the expression of sexual behavior in rams. This effect has not been reported in the sexual development of male cattle and swine.

1135. Price, Edward O., Reid Borgwardt, and Martin R. Dally. 1996. **Heterosexual experience differentially affects the expression of sexual behavior in 6- and 8-month-old ram lambs.** Appl. Anim. Behav. Sci. 46(3-4):193-199.
Abstract: The sexual performance of 6- and 8-month-old ram lambs (175 and 26 subjects, respectively) was quantified when individually exposed to four estrous ewes for 30 min on four occasions 7 days apart. In addition, half of the animals in each age class (experimental subjects) were exposed to 16 estrous females for 6, 16, or 24 h after testing on Test Days 1, 2, and 3. Control subjects received no additional exposure to females. Sexual performance improved for all groups over the 4 weeks of testing. However, 6-month control rams improved at a slower rate than 6-month experimental rams. By the fourth weekly test, 58% of the control rams and 85% of the experimental rams had attained ejaculatory competence. Treatment

did not affect the sexual performance of the 8-month-old subjects; both control and experimental groups had attained 100% ejaculatory competence by the fourth week. Length of the extended exposure to females did not affect the results. It was concluded that the sexual responsiveness of ram lambs toward females is sufficiently undeveloped at 6 months (i.e. puberty) that extended exposure to sexually receptive ewes is needed for many males to exhibit adult levels of sexual performance. At 8 months, the sexual development of ram lambs has sufficiently matured so that relatively brief encounters with estrous females releases the full expression of adult sexual behaviors. These findings may be of benefit to sheep breeders who wish to use ram lambs in their breeding programs.

1136. Price, Edward O., Reid Borgwardt, Martin R. Dally, and P. H. Hemsworth. 1996. **Repeated matings with individual ewes by rams differing in sexual performance.** J. Anim. Sci. 74(3):542-544.
Abstract: Twenty-four sexually mature rams were individually exposed to 10 estrous ewes on three occasions to determine the relationship between levels of sexual performance (ejaculation rate or serving capacity) and the incidence of repeated matings (ejaculations) with individual ewes. Rams that attained six ejaculations in a relatively short period of time (HP rams) mated fewer times with individual ewes than low-performing (LP) rams ($P < .01$). As a consequence, HP rams tended to mate with a greater number of different ewes than did LP rams ($P < .06$). In addition, time required to attain six ejaculations was inversely correlated with the number of different ewes mated ($P < .03$). The HP rams did not differ from LP rams in the number of different ewes investigated and courted. These findings highlight the value of using rams with relatively rapid ejaculation rates when breeding large groups of naturally cycling or synchronized ewes

1137. Price, Edward O., Martin R. Dally, and Reid Borgwardt. 1996. **Early sexual experience improves ram breeding.** Calif. Agric. 50(4):37-40.
Abstract: Research on the development of sexual behavior in male sheep has demonstrated that ram lambs are sufficiently mature in their first year of life to assume an important role in sheep-breeding programs. Lack of sexual experience in the first year can result in sexual inactivity, reduced mating rates, and abnormal sexual orientation in the yearling year. Variability in rams' sexual performance can be evaluated by simple mating tests administered prior to the breeding season. The greater reproductive success of high-performing rams is achieved not only by a higher rate of mating but also by a tendency to distribute matings over more females. High libido rams are not inherently more aggressive.

1138. Price, Edward O., Reid Borgwardt, Agustin Orihuela, and Martin R. Dally. 1998. **Sexual stimulation in male sheep and goats.** Appl. Anim. Behav. Sci. 59(4):317-322.
Abstract: Previous research has shown that the sexual performance of male goats is enhanced by viewing the mating activities of other males prior to being placed with sexually receptive females. This same experience has no effect on the sexual performance of male sheep. In this experiment, 14 male goats and 17 rams were individually allowed to sniff and nuzzle the anogenital region of an estrous female and engage in premating behaviors, but not mount for 20 min immediately prior to the administration of 30-min sexual performance tests. A female-absent control treatment was administered to these same animals prior to sexual performance tests. In the sexual stimulation treatments, male goats were more sexually active than rams ($P < 0.001$ for all variables). However, sexual stimulation did not affect the subsequent sexual performance of either species ($P > 0.20$ for all variables). Male goats and sheep did not differ ($P > 0.05$) in number of completed matings (services), but male goats exhibited more mounts without ejaculation ($P < 0.001$) and more mounts per service ($P < 0.001$) than rams. These results are discussed in terms of the reproductive advantage of sexual stimulation to male ungulates in the context of male-male competition vs. the absence of male competitors.

1139. Price, Edward O., Martin R. Dally, Hans W. Erhard, M. Gerzevske, M. Kelly, N. Moore, A. Schultze, and C. Topper. 1998. **Manipulating odor cues facilitates add-on fostering in sheep.** J. Anim. Sci. 76:961-964.
Abstract: Manipulating the odor of a ewe's own and alien lambs has been used to facilitate fostering a second lamb on ewes with a single offspring (add-on fostering). Previous research has demonstrated that familiar odor cues must be present on the own and alien young to achieve successful and rapid adoptions. Familiar odors may consist of natural own-lamb odors or artificial odors previously applied to the lambs involved. In this study (Exp. 1), an artificial odorant (neatsfoot oil) was applied to the own and alien lambs shortly after birth to establish a common familiar odor. Acceptance tests were conducted daily over a 72-hour period. In Exp. 2, neatsfoot oil was again used as a common artificial odorant to facilitate add-on fostering, but, in addition, the natural odors of own and alien lambs were transposed by exchanging cloth stockinette jackets worn by the lambs. In Exp. 1, 9 of 18 ewes (50%) met the criteria for accepting their own and alien lambs within 72 hours. Seven of these 9 ewes (78%) accepted the alien lamb immediately. In Exp. 2, 24 of 30 ewes (80%) accepted their own and alien young, and 20 of the 24 acceptances (83%) were immediate. We conclude that add-on fostering may be limited only by our inability to properly match familiar-odor cues on own and alien lambs.

1140. Price, Edward O. 1999. **Suckling behavior.** Pp. 681-685 *in:* E. Knobil and J. Neill (eds.), Encyclopedia of Reproduction, Vol. 4. Academic Press, San Diego, CA.
Abstract: This article describes suckling behavior, an innate mammalian behavior by which young extract milk from the mammary gland of lactating females. The author discusses development of this behavior, stimuli that elicit suckling, the importance of colostrum, teat preferences, suckling frequency, and atypical suckling behavior.

1141. Price, Edward O., Reid Borgwardt, and Martin R. Dally. 1999. **Effect of early fenceline exposure to estrous ewes on the sexual performance of yearling rams.** Appl. Anim. Behav. Sci. 64:241-247.
Abstract: Previous research has demonstrated that early heterosexual (mating) experience improves the sexual performance of yearling rams. The present study examines the effect of early fenceline (FL) contact of young ram lambs with estrous females on their sexual performance as yearlings. A total of 104 rams, 7-8 months of age, were given no contact (NC), direct contact (DC), or FL exposure to estrous ewes during a 3-week period in the fall breeding season. When initially tested for sexual performance as yearling rams at 18-19 months, 8 of 21 (38%) FL rams exhibited no sexual interest in estrous females (did not court or mount females), a result that was intermediate to and not significantly different from ($P > 0.05$) the incidence of sexual disinterest exhibited by NC (59%) and DC rams (15%). The difference between NC and DC rams was significant ($P < 0.002$). In addition, 12 of 21 (57%) yearling FL rams initially mounted estrous ewes, a result that was intermediate to and not significantly different from ($P > 0.05$) the incidence of mounting by NC and DC males (41% vs. 85%, respectively). Again, NC and DC rams differed from one another ($P < 0.002$). Treatment did not affect frequencies of mounting with and without ejaculation by the sexually active rams ($P = 0.11$ and 0.36, respectively). FL rams that were sexually inactive in Year 2 spent less time ($P < 0.02$) in Year 1 within a body length of the fence separating them from the ewes than FL rams that were sexually active in Year 2. FL proximity scores in

Year 1 were positively correlated (r_s = 0.49; P < 0.05) with ejaculation frequencies in Year 2. It was concluded that early FL contact with ewes only partially substitutes for direct heterosexual (mating) experience in enhancing the sexual performance of yearling rams. Also, measures of FL proximity to estrous ewes can serve as an aid in predicting relative levels of sexual performance in rams.

Ewe with young lamb, April 1996

1142. Price, Edward O., Agustin Orihuela, Valli Parthasarathy, Reid Borgwardt, and Martin R. Dally. 1999. **Yearling rams initially disinterested in estrous ewes subsequently exhibit subnormal sexual performance.** Appl. Anim. Behav. Sci. 64:235-240.
Abstract: Sexual performance tests are useful in describing and predicting relative differences in the sexual performance of male ungulates. A significant percentage of domestic yearling rams are sexually inhibited when first exposed to estrous ewes. The following study demonstrates that such sexually-inhibited yearling rams subsequently exhibit subnormal sexual performance once they become sexually active. Individual 30-min sexual performance (serving capacity) tests were administered to 73 Targhee rams at 18-19 months of age. Forty-one rams (56%) successfully mated with estrous ewes on first exposure (Test 1). Seventeen rams (23%) commenced servicing ewes on Tests 2, 3, or 4. Of the remaining 15 rams, 12 attained ejaculations in subsequent tests but only after being housed continuously with females. These three groups of rams were compared for frequency of mounts with and without ejaculation plus a measure of mount efficiency (mounts per ejaculation) during the third and fourth tests in which they serviced females. Rams that successfully mated in Test 1 subsequently exhibited higher frequencies of ejaculation (P < 0.05) than rams that attained ejaculations for the first time in Tests 2, 3, or 4 or after continuous exposure to females. Ejaculation frequencies were similar for the two delayed groups. The three groups did not differ for mounts without ejaculation or mating efficiency. It was concluded that the sexual performance of yearling rams who initially fail to mate with estrous ewes is likely to be subnormal relative to the sexual performance of rams who successfully mate when first exposed to females.

1143. Price, Edward O., Clover J. Bench, Reid E. Borgwardt, and Martin R. Dally. 2000. **Sexual performance of twin ram lambs and the effect of number and sex of contemporary siblings.** Appl. Anim. Behav. Sci. 68:199-205.
Abstract: The objectives of this investigation were to determine the degree of correspondence in the sexual performance of twin male sheep and to compare the sexual performance of ram lambs born co-twin to another male (M-M), co-twin to a female (M-F), and as single (S) offspring. Individual ram lambs (n = 117), including 13 M-M twin sets, were exposed to four estrous ewes for 30 min at 7-day intervals over a 4-week period at 8 to 9 months of age. Frequencies of ejaculation (serving capacity) and mounts without ejaculation were recorded. M-M males averaged 2.9 ejaculations and 13.1 mounts per test. Individuals within 9 of the 13 M-M twin sets (69%) differed by an average of 0.5 or fewer ejaculations per test. Although variability within M-M twin sets was very low, variability between the 13 M-M twin sets was also low (coefficient of variation = 10.6%). Consequently, frequencies of both ejaculation and mounting (without ejaculation) within the 13 twin sets were not correlated (P = 0.50 and P = 0.10, respectively). When the progeny of individual sires were compared, mounting frequencies were correlated (P < 0.02) but not ejaculation rates (P = 0.26) or mounts without ejaculation (P = 0.98). It was concluded that the sexual performance of related individuals is likely to be very similar and that the number and sex of contemporary siblings does not necessarily influence rates of mounting and ejaculation.

1144. Price, Edward O., Reid E. Borgwardt, and Martin R. Dally. 2001. **Male-male competition fails to sexually stimulate domestic rams.** Appl. Anim. Behav. Sci. 74:217-222.
Abstract: Male domestic sheep are non-territorial and mate in multiple-male mating groups in which males compete for access to females. The following study tests whether rams are sexually stimulated by participation in or observation of male-male competition for estrous ewes and if so, whether the response is affected by the sexual performance level of rams. Twenty-eight sexually-experienced yearling rams were given individual 30-min sexual performance tests immediately after 15 min of 1) direct competition (DC) with other rams for 10 estrous ewes whose perinea had been covered to prevent intromissions, 2) observing rams competing for estrous females (OC), 3) observing other rams without females (OR), and 4) observing an empty pen (EP). The DC and OC treatments did not enhance sexual performance relative to the control treatments. Instead, the DC treatment resulted in a reduce rate of ejaculation, possibly because of the physical exertion of repeatedly mounting females and accompanying male-male agonistic interactions. In addition, some rams may have become sexually inhibited because of the inability to attain intromissions in the DC treatment. High- and low-performing rams did not differ in their response to the four treatments. Frequencies of mounts without ejaculation and mounts per ejaculation were not influenced by treatment or sexual performance level. It was concluded that observing rams engaged in competition for estrous females does not improve sexual performance and that sexual performance is reduced following direct competition for females.

1145. Price, Edward O., and G. Eric Bradford. 2001. **Sheep research offers alternatives to improve production.** Calif. Agric. 55(6):19-25.
Abstract: Scientists working at the Hopland Research and Extension Center have made important contributions to the sheep industry in breeding and genetics, and in the understanding of animal behavior. A long-term experiment involving HREC was initiated in 1960 to evaluate the effects of selection environment on sheep performance under range conditions. Selection of the UC Davis flock, representing the favorable conditions typical of purebred flocks where most breeding rams are raised, resulted in more within-flock improvement in weaning weight than selection under range conditions at Hopland. However, when the UC Davis- and Hopland-selected lines were compared under range conditions at HREC, the two were equal in weaning weight, and the Hopland line was superior in reproduction and total productivity. We concluded that selection

should take place in the environment of use. In the late 1970s, investigations were initiated to develop cost-efficient techniques for fostering lambs to unrelated ewes; an effective new method was developed using stockinette jackets and neatsfoot oil to transfer odors. Likewise, research on sexual behavior has resulted in several relatively simple behavioral tests that can be used to determine the performance of rams.

1146. Quirke, J. F., G. Eric Bradford, Thomas R. Famula, and Donald T. Torell. 1982. **Ovulation rate, fertility and embryo survival in selected lines of Targhee sheep (Abstract).** J. Anim. Sci. 55(Suppl. 1):160.
Abstract: Ovulation rate (OR) was measured by laparoscopy during two consecutive cycles in control Targhee (C) ewes and in line which had been subjected to long-term selection for 120-day weight (2 lines: HW and DH) and litter size at birth (T). The ewes were single sire mated at the ovulation prior to the second ovarian inspection and the relationship between OR, conception rate, and embryo survival examined. Body weight and OR increased with age in all lines and there was no evidence for any line × age interaction with respect to either parameter. Both variables increased between the first and second ovarian examination in all lines with the exception of DH; although there was an increase in mean ewe body weight in this line there was no change in OR. There was a positive and significant association between body weight and OR and the relationship was not heterogenous among the lines. The number of ewes examined and the line means for OR (sum of the two measures) and body weight (kg) were as follows: (a) Control: 100, 2.78, 51.5; (b) Weight Selected Lines: HW: 55, 3.27, 57.9; DH: 53, 2.92, 58.3; (c) T: 117, 3.15, 53.6. The mean OR values after adjustment for differences in live weight were 2.99, 3.11, 2.74, and 3.25 for C, HW, DH, and T lines respectively. Conception rate was higher in ewes with two or more ovulations (77%) than those with one (62%). Embryo survival (lambs born/OR) in pregnant multiple ovulating ewes was, for C, 86; HW, 83; DH, 82; and T, 86%. Following first service only, ewes of lines C, HW, DH, and T had conception rates of 69, 61, 71, and 79%; 1.47, 1.55, 1.31, and 1.55 lambs born per ewe lambing; and 1.02, .94, .92, and 1.22 lambs born per ewe mated.

1147. Quirke, J. F., G. Eric Bradford, T. R. Famula, and Donald T. Torell. 1985. **Ovulation rate in sheep selected for weaning weight or litter size.** J. Anim. Sci. 61(6):1421-1430.
Abstract: Ovulation rate was measured by laparoscopy at two consecutive cycles on 366 ewes 2 years old and over and 85 yearling ewes of 5 lines of Targhees from the base population; 53 yearling linecross ewes were also included. The lines were two unselected controls (HC1 and DC), two selected for 21 years for increased 120-day weight (HW and DH), and one selected for 19 years for multiple births (T). Ewes were synchronized in late July or early August at the start of normal breeding season with intravaginal pessaries impregnated with 60 mg methylacetoxyprogesterone and examined at first and second estrus. Ovulation had occurred in both cycles in 327 (89%) and 117 (85%) of the mature and yearling ewes, respectively. Overall mean numbers of corpora lutea at first and second estrus were 1.42 and 1.63, respectively, for ewes two years old and over and 1.20 and 1.44 for yearlings, indicating an effect of synchronizing treatment, season, flushing, or a combination of these. Among mature ewes, ovulation rate was higher ($P < .05$) in DH (+.20), HW (+.19), and T (+.16) than in controls at first estrus, and in HW (+.29) and T (+.21) but not in DH (-.04) at second estrus. Among yearlings, differences were significant only at second estrus (HW, +.40; T, +.35) and again not for DH (+.08). The failure of DH to increase in ovulation rate from first to second estrus as did other lines was transmitted to linecross progeny. Body weight within line affected ovulation rate significantly, with a greater effect at second estrus, in both age groups. Adjustment for body weight removed the difference between HW and controls but not between T and controls. Repeatability of corpora lutea count was .27 and .25 for mature and yearling ewes, respectively.

1148. Ramdas, Sagari, Martin R. Dally, G. Eric Bradford, and Hakan Sakul. 1993. **Lamb and wool production of Targhee and prolific breed crossbred ewes.** Sheep Res. J. 9(2):62-70.
Abstract: The lifetime lamb and wool production of ¼ Barbados-¾ Targhee (BT) ewes was compared with pure Targhee (T), Polypay (PP), ¼ Finn-¼ Dorset- ½ Targhee (FDT), and ¼ Finn-¼ Rambouillet-½ Targhee (FRT) over four production years under range conditions in California. Ewes were born in two years except PP, which had only one age group. Ewes were flock-mated to Suffolk sires. BT ewes weaned the most pounds of lamb per ewe (26.7 kg per ewe in the flock and 28.0 kg per ewe lambing) and shared the highest overall wool and lamb productivity index (25.3 kg) with T. They also had highest estimated efficiency for total productivity when ewe size was considered, although breed differences were not significant. This was largely due to their higher fertility (93%), litter size weaned (1.26), and lamb viability (80%). BT also exhibited a small but significant earlier lambing date than the other groups. FRT ranked next for the above traits, followed by T and FDT. FRT produced the highest litter size (1.48), followed by BT (1.42), T (1.35), and FDT (1.31). The multiple-birth selected Targhee line did not differ significantly from ¼ Finns and ¼ Barbados for litter size born (1.45) and weaned (1.15). Repeatability of litter size varied from 0 to 0.14. Lambs born to ¼ Finns (3.4 kg) were 10% to 13% lighter at birth than T and BT. Mature BT ewes were lighter ($P < 0.01$) than the other groups. Significantly lighter fleeces (2.65 kg and 3.12 kg) were produced by ¼ Barbados and ¼ Finns than by T (3.61 kg), and BT had slightly coarser wool. PP exceeded T in yearling and adult mating weight, with fleece traits comparable to other ¼ Finns. Among the three ¼ Finn groups, PP had the highest mean litter size (1.45) and did not differ from FRT for number (1.17) and total weight of lambs weaned (26.4 kg).

1149. Rattray, P. V., W. N. Garrett, H. H. Meyer, G. E. Bradford, N. E. East, and N. Hinman. 1973. **Body and carcass composition of Targhee and Finn-Targhee lambs.** J. Anim. Sci. 37(4):892-897.
Abstract: The carcasses and wool free empty bodies of 15 unselected Targhee, 15 weight selected Targhee (10 years selection for heavy weaning weight), 13 ½ Finn-½ Targhee and 17 ¼ Finn-¾ Targhee lambs were chemically analyzed. Each genotype group was comprised of initial slaughter, maintenance fed and *ad libitum* fed animals from a comparable slaughter experiment. *Ad libitum* animals were higher in fat and lower in water, protein, and ash than animals from the other treatments. Maintenance animals had a higher fat content than the initial slaughter animals and on a fat-free dry matter basis they had a lower protein and higher ash content than *ad libitum* or initial slaughter animals. The ¼ Finn lambs in the average had higher fat and energy and lower water, protein, and ash contents than did other genotypes, while the weight selected lambs were lower in fat and energy, but higher in water, protein, and ash contents than the other genotypes. Genotypes were not significantly different in any composition parameter on a fat free basis.

1150. Rattray, P. V., W. N. Garrett, H. H. Meyer, G. E. Bradford, N. Hinman, and N. E. East. 1973. **Net energy requirements for growth of lambs age three to five months.** J. Anim. Sci. 37(6):1386-1389.
Abstract: Eighty-four white-face wether lambs were used in a comparative slaughter experiment to determine their net energy requirements for maintenance (NE_m) and gain (NE_g). The metabolizable energy (ME) content of the diet was 2.67 and 2.59 kcals ME/g DM when fed at either a maintenance or *ad libitum* level of feeding, respectively. The ME was used for maintenance and gain with efficiencies of 65.7% and 40.8%, respectively. The NE_m and NE_g contents of the diet were 1.75 and 1.04 kcals NE/g DM,

respectively. The daily NE_m requirement was 79.4 kcal/$W_{kg}^{3/4}$ and the daily NE_g requirement was 322.2 kcal/kg gain/$W_{kg}^{3/4}$.

1151. Reynolds, L. L., and Dan L. Brown. 1991. **Assessing dairy potential of western white-faced ewes.** J. Anim. Sci. 69:1354-1362.
Abstract: Two experiments were conducted to examine milk producing ability of Western white-faced sheep and to identify traits that correlate well with milk production. In Experiment 1, 31 Targhee ewes were milked and five samples were taken during 107-day lactations in which the ewes nursed twin lambs. Milk yield and composition, lamb weights, ewe weights, wool growth, and udder size also were measured. In Experiment 2, 24 ewes (Rambouillet × Finn-Dorset) were separated from their lambs at 7 weeks and milked twice per day for eight more weeks, during which milk yield and composition, feed consumption, udder width, and ewe weights were measured. Results from Experiment 1 showed that lamb 30-day weights, ewe weights at breeding time, and udder width at peak lactation were highly correlated with suckled milk yield (r = .81, .75, and .66, respectively). Results from Experiment 2 indicated that lamb weights and ewe weights were not useful for predicting milk yield in dairy ewes, but feed intake and udder width were (r = .74 and .86, respectively). Single-day milk yield measurements were excellent estimators of total lactation yield in both experiments. Milk yields averaged 1,714 g/day in the suckled ewes and 477 g/day in the dairy ewes.

1152. Rosiere, R. E., and Donald T. Torell. 1985. **Nutritive value of sheep diets on coastal California annual range.** Hilgardia 53(1):1-19.
Abstract: Diets of sheep on California annual range in the northern Coast Mountains were evaluated at various seasons and stages of plant growth on grass-woodland and improved grassland range grazed yearlong at three grazing intensities. Nutritive content of forage samples collected by esophageal-fistulated ewes, including organic matter digestibility, digestible energy, crude protein, ether extract, fiber constituents, and minerals, was compared with nutritive content of herbage from both range (vegetative cover) types and with nutrient requirements of sheep. Diets from grassland improved by seeding to subterranean clover were more digestible and had more crude protein and digestible energy than diets from woodland range. There were differences in contents of various nutrients among seasons and phenological stages (e.g., more protein and energy in fall and winter than in summer) but not among grazing intensities. Based on nutrient concentrations, diets were generally adequate for brood ewes except at plant maturity on woodland range when protein and energy could be deficient. Grazing selectivity occurred for some nutrients but not consistently. Associations among nutritional variables suggested that acid detergent fiber was a good indicator of forage nutritional value. Acid detergent lignin and cellulose were the best predictive variables for organic matter digestibility.

1153. Rosiere, R. E., and Donald T. Torell. 1986. **Performance of sheep grazing California annual range.** Range Sci. Rep. 7, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 16 pp.
Abstract: A sheep grazing trial was conducted in coastal northern California on two subtypes of annual range. Grassland which was improved by fertilization and seeding to subterranean clover and grass-woodland were grazed continuously for five years by dual purpose ewes at moderate, moderately heavy, and heavy grazing treatments (stock rates of .25, .75; 1.3, 2.1; and 3.2, 4.0 ewes/a on woodland and grassland range, respectively). Responses in lamb weaning weight, ewe fleece weight, lamb crop percentage, ewe mortality, and turnoff of feeder lambs and grease wool were measured. Lamb and wool production was about six-fold greater on improved grassland than on grass-woodland range (146 vs. 26 lb of lambs/a; 19.7 vs. 3.4 lb of wool/a). Stocking rate had no significant effect on any performance parameter, but weaning weights tended to decrease as stocking increased on woodland and appeared heaviest under heavy grazing on grassland. Lamb crops weaned from woodland ranges tended to decline at stocking rates above moderate grazing. There was a trend for increasing wool and feeder lamb yield/acre with rising stocking rates on grassland. On woodland, turnoff increased only at the highest stocking rate. Increasing turnoff from grass-woodland range by raising stocking rates required supplementation. This prevented ewe mortality and reductions in lamb crop from exceeding those under moderate grazing. Moderate stocking of woodland range (1.5 - 2.5 ewe/a under yearlong grazing) was suggested for sheep operations with less intensive management. Heavy stocking (25 ewes/a yearlong) was recommended for grassland seeded to subterranean clover.

Research ewes on dryland range, July 1983

1154. Rosiere, R. E., and Donald T. Torell. 1996. **Performance of sheep grazing California annual range.** Sheep and Goat Res. J. 12(2):49-57.
Abstract: A sheep grazing trial was conducted in coastal northern California on two subtypes of annual range. Grassland improved by fertilization and seeding to subterranean clover (*Trifolium subterraneum*) and grass-woodland were grazed continuously for five years by Targhee-type ewes at 100%, 150% and 200% of moderate grazing intensity (stocking rates of 0.6, 1.8, 3.2 and 5.3, 8.0, 10.0 ewes/ha on woodland and grassland range, respectively). Sheep performance was compared among stocking rates and between range subtypes over years by evaluating responses in lamb weaning weight, ewe fleece weight, lamb crop percentage, ewe mortality, and turnoff of feeder lambs and grease wool. Turnoff of lambs and wool was about six-fold greater on improved grassland (IG) than on grass-woodland (GW) range (164 vs. 29 kg of lambs/ha). Stocking rate had no significant effect on any performance variable, but weaning weights tended to decrease as stocking rate was increased on woodland and appeared heaviest under 200% moderate grazing on IG range. Lamb crops weaned from woodland ranges tended to decline at stocking rates above moderate grazing. There was a trend for increasing wool and feeder lamb yield/ha with rising stocking rates on IG range. On GW range, turnoff increased only at the highest stocking rate. Increasing turnoff from GW range by raising stocking rates required survival feeding. This prevented ewe mortality and reductions in lamb crop from exceeding those under moderate grazing. Moderate stocking of GW range (0.6 to 1.0 ewe/ha under year-long grazing) was suggested for sheep operations with less intensive management. Stocking at 200% of moderate (10.0 ewes/ha year-long) was recommended for annual grassland seeded to subterranean clover.

1155. Sainz, R. D. 2001. **Callipyge meat a tough sell.** Calif. Agric. 55(6):25.
Abstract: In 1983, a sheep breeder in Oklahoma noticed a ram with

exceptional muscling, especially in the hindquarters. This ram was mated to normal ewes, and the condition was passed on to their offspring. Eventually the extra muscling was found due to a spontaneous mutation, a natural change in the animal's genetic code. Because the muscle hypertrophy (enlargement) is most pronounced in the hindquarters, the condition was named *callipyge*, a Greek word meaning "beautiful buttocks." Needless to say, sheep breeders were immediately interested in the meat production potential of lambs carrying the callipyge gene. In an experiment conducted at Hopland and UC Davis, lambs expressing the callipyge phenotype produced leaner, more muscular carcasses that yield more saleable quantities of meat than normal lambs. However, industry adoption of the callipyge genotype is limited by the increased toughness in some hypertrophied muscles, which seems to be related to high calpastatin activity and low myofibrillar fragmentation. Several technologies have been developed to overcome this problem, but so far none has been adopted by the packing industry because of high initial costs and uncertain benefits.

1156. Sakul, Hakan, G. Eric Bradford, Robert H. BonDurant, Gary B. Anderson, and S. E. Donahue. 1993. **Cryopreservation of embryos as a means of germ plasm conservation in sheep.** Theriogenology 39:401-409.
Abstract: Embryos were collected from 4 lines of Targhee sheep between 1986 and 1990. The lines were selected for preweaning growth rate (Lines DH and HW) or for multiple births (Line HT); Line C served as an unselected control group. Estrus was synchronized using fluorogestone acetate-impregnated vaginal pessaries, and ewes were superovulated with FSH. Embryos at the morula or blastocyst stage were surgically recovered from mature ewes at Days 5 to 6 and were frozen following morphological evaluation. The overall average number of freezable embryos per collection was 2.9 and did not differ significantly among years or among lines. Of the embryos collected between 1986 and 1988, 92 were transferred to 53 recipients in 1989, producing 53 lambs. Survival rates were 60.9% and 47.8%, respectively, for embryos evaluated as good and fair after thawing. Good-quality blastocysts yielded the highest survival rate (64.4%). Analyses indicated no significant effects of line, developmental stage, or embryo evaluation on the incidence of lambing. It was concluded that embryos of morula or blastocyst stage can be successfully frozen for extended periods. The data on embryo yield and survival following cryopreservation were used to calculate numbers of donors needed to preserve and reconstitute a population of specified size.

1157. Sakul, Hakan, Martin R. Dally, and G. Eric Bradford. 1993. **Evaluation of Australian Merino and U.S. sheep breeds for growth and carcass traits.** J. Anim. Sci. 71:363-368.
Abstract: One hundred twenty 4-mo-old wether lambs born to Targhee ewes and sired by six rams each from Merino (Finewool, FM and Strongwool, SM), Rambouillet (Dubois, DR and Texas, TR), and Targhee (T) breeds were randomly assigned to predetermined slaughter weight groups of 43, 48, 52, and 57 kg and evaluated for growth and carcass traits. Overall mean average daily gain and feed conversion rate (FC, kilograms of feed/kilogram of gain) were .28 and 6.4 kg, respectively; T grew the fastest (.31 kg) and FM grew the slowest (.23 kg). Targhee and SM had the best FC (6.2), whereas FM (6.8) had the poorest FC ($P < .05$). Overall mean backfat thickness (BT) and carcass fat (CF) were 4.8 mm and 25.6%, respectively. Targhee had the lowest (24%) and FM the highest (27.8%) CF percentage ($P < .05$). Differences ($P < .05$) were observed for BT and CF among slaughter weight groups; overall means for both traits gradually increased from the 43- to the 57-kg groups. Separate analysis of the 43- and the 48-kg groups indicated nonsignificant breed differences for feed traits, whereas significant differences still existed for CF. It was concluded that Merino strains grew more slowly, were less efficient in postweaning growth, and had higher carcass fat content than U.S. breeds at a constant slaughter weight; SM were more comparable to U.S. breeds than were FM. Merino-cross lambs should be slaughtered at lighter BW to avoid excessive carcass fat.

1158. Sakul, Hakan, G. Eric Bradford, Martin R. Dally, Thomas R. Famula, and Curtis M. Finley. 1994. **Growth rate in sheep selected for weaning weight or litter size in a range environment.** Pp. 59-62 *in:* Proc. 5th World Congr. on Genetics Appl. to Livest. Prod., Vol. 18, Guelph, Canada.
Abstract: Genetic trends, and phenotypic and genetic parameters are reported for 4 lines of grade Targhee sheep raised in a range environment for over 30 years. Two lines (DH and HW) were selected for individual 120-day weights, one for multiple birth (HT); HC was an unselected control. Phenotypic response to selection for 120-day weight has occurred, but at a slow rate. An examination of breeding values indicated that both DH and HW lines responded to selection continually and until the mid-1980s, but the response seemed to cease in line HW thereafter; the trend in DH was less clear. Low selection pressure and inbreeding were ruled out as primary reasons for this, and we hypothesize that inadequate nutrition may have hindered the selection response. Inbreeding increased almost linearly during the experiment, reaching approximately 11% in HC and HW, and 6% in HT by 1992. Estimates of direct and maternal heritabilities were .16 and .22, respectively, in the base population. Genetic correlation between direct and maternal effects was .12. Realized heritabilities, calculated from response / selection differential measured in each line, were .05, .06, and .07 for DH, HT, and HW, respectively. The difference between estimated and realized heritabilities implies that the environment did not permit the full expression of the genetic potential for growth.

1159. Sakul, Hakan, G. Eric Bradford, and Martin R. Dally. 1999. **Selection for litter size or weaning weight in range sheep. I. Selection practiced and direct response.** Sheep and Goat Res. J. 15(3):126-137.
Abstract: Selection was practices for more than 30 years for increased litter size or 120-day weight in closed lines of grade Targhee sheep, in a range environment characterized by relatively low forage quantity and/or quality during several months of each year. Initial screening of a flock for high litter size ewes produced an increase of .09 lambs/litter (6%), but an additional 30 years of selection produced a further increase of only .08, for an estimated realized heritability for the latter period of .011. In spite of this low value, the total response represents a potentially significant economic advantage for the selected line over the unselected control. Realized heritability for 120-day weight was .06 and .08 in two selected lines, also lower than many reported estimates of heritability for the trait, but the accumulated gain represent approximately a 17% increase above the control. One of the two weight selected lines also showed a significant increase in litter size. Correlated responses and estimated impacts of the selection on total lamb production are reported in a companion paper (*see* Bradford et al. 1999).

1160. Scrivner, Jerry H., Martin R. Dally, and Walter E. Howard. 1987. **Survival analysis of single and twin lambs.** J. Range. Manage. 40(2):185-187.
Abstract: We illustrate the use of life tables and survival analysis for evaluating data on livestock losses. The techniques are used to compare the rate of coyote predation on single and twin lambs. Based on the number of lambs known to have been killed by predators, the survivorship of single and twin lambs at Hopland was not significantly different ($P > 0.05$) for any year of the study. Survival functions which can be generated and used to evaluate data on livestock losses include the cumulative proportion of livestock surviving at the end of an interval, probability density, and hazard rate.

1161. Selee, Scott, and Monte Bell. 1987. **Using SHEP II: a sheep record program for the PC.** Pp. 33-36 *in:* Proc. Sheep Breeding School, Hopland Field Station, Univ. Calif., Hopland, CA, Jun. 19-20.
Abstract: The authors describe a new computer program, SHEP II, developed by Oregon State University graduate student Robert Lewis for managing commercial sheep production records. The program requires that all sheep, even lambs that die at birth, have individual identification numbers. Preliminary testing of this program using data from a large commercial herd indicates the program is very satisfactory.


A. H. Murphy

UC Davis veterinary scientist George Crenshaw speaks to Animal Health Field Day participants while Marshall Slater holds sheep, February 1972

1162. Sidahmed, Ahmed E. 1976. **Effect of the length of fasting on intake, *in vitro* digestibility and chemical composition of forage samples collected by esophageal fistulated sheep.** M.S. Thesis, Univ. Calif. Davis. 78 pp.
Abstract: Four sheep with esophageal fistulae were used to measure the effect of different periods of fasting on the weight and chemical composition of samples collected from four pasture types. The four periods of fasting used were 0, 12, 24, and 36 hours arranged to occur in a Latin square sequence; the four pasture types were native, improved, *Phalaris tuberosa*, and chamise. Each sheep grazed for 1 hr and each sample was lyophilized, weighed, and *in vitro* digestibility, percentage nitrogen, ash, silica, neutral and acid detergent fiber (NDF, ADF), lignin (ADL), and hemicellulose were measured. There were significant differences between pastures in all constituents measured. Pooling all results showed that fasting significantly affected sample size and ADF, however, within pastures the regression coefficient of some parameters against hours of fasting were significant. Notable among these were the significant negative coefficients for *in vitro* digestibility and ash for the native pasture, and the positive coefficients for nitrogen for the *Phalaris* pasture and silica, ADF, and NDF for the chamise pasture. It was concluded that moderate fasting did not have a pronounced effect on the composition of the samples collected, but the direction and magnitude of the effect of fasting was dependent on the pasture.

1163. Sidahmed, Ahmed E., J. G. Morris, William C. Weir, and Donald T. Torell. 1977. **Effect of the length of fasting on intake, *in vitro* digestibility and chemical composition of forage samples collected by esophageal fistulated sheep.** J. Anim. Sci. 46(4):885-890.
Abstract: Four sheep with esophageal fistulae were used to measure the effect of different periods of fasting on the weight and chemical composition of samples collected from four pasture types. The four periods of fasting used were 0, 12, 24, and 36 hours arranged to occur in a latin square sequence; the four pasture types were native, improved, *Phalaris tuberosa*, and chamise. Each sheep grazed for 1 hr and each sample was lyophilized, weighed, and *in vitro* digestibility, percentage nitrogen, ash, neutral and acid detergent fiber (NDF, ADF), lignin (ADL) and hemicellulose were measured. There were significant differences between pastures in all constituents measured. The results showed that fasting significantly affected sample size and ADF; however, within pastures the regression coefficient of some parameters against hours of fasting were significant. Notable among these were the significant negative coefficients for *in vitro* digestibility and ash for the native pasture, and the positive coefficients for nitrogen for the *Phalaris* pasture and ADF and NDF for the chamise pasture. It was concluded that moderate fasting did not have a pronounced effect on the composition of samples collected, but the direction and magnitude of the effect of fasting was dependent on the pasture.

1164. Sidahmed, Ahmed E., J. G. Morris, and Steven R. Radosevich. 1979. **Relationships between the botanical and the chemical constituents of the diet selected by Spanish goats grazing chaparral.** Proc. West. Sect. Am. Soc. Anim. Sci. 30:166-169.
Abstract: The browsing preference and feed intake of Spanish goats was studied on a 0.2-ha chaparral field in which a wildfire had occurred five years earlier. The dominant shrub species were chamise, scrub oak, eastwood manzanita, and cupleaf ceanothus. Less than two weeks before sampling, an unseasonal rain contributed to the growth of herbaceous vegetation. Shrub density, cover, and crown volume measurements were obtained from ten permanent transects. Four goats with esophageal fistulae were used to sample the forage. Total fecal excretion was measured on five non-fistulated goats. Feed intake was calculated from the fecal output and the percentage *in vitro* dry matter digestibility (IVDMD) of the esophageal samples. The browsing preference of Spanish goats was highly directed (about 80%) toward scrub oak and chamise. The remainder of the diet was mostly grasses and forbs, while eastwood manzanita and cupleaf ceanothus made a negligible contribution. Shrub preference was not related to availability as manzanita and ceanothus had the highest volume and were the most abundant species. Regression models to estimate IVDMD from the diet's chemical and botanical contents were derived. IVDMD of esophageal samples was positively correlated with the content of grass and forbs and negatively correlated with the sum of the percentages of scrub oak and chamise.

1165. Sidahmed, Ahmed E., James G. Morris, and Ling J. Koong. 1980. **Comparisons of methods of estimating apparent digestibility of browse and herbaceous feed mixtures by goats (Abstract).** *In:* Proc. 72nd Ann. Mtng. Am. Soc. Anim. Sci., Cornell Univ., Ithaca, NY.
Abstract: A digestibility trial using Spanish goat wethers was conducted on mixtures of browse species: chamise, scrub oak, and manzanita (*Arctostaphylos glandulosa*) alone or in a combination with sudan grass and alfalfa (SA) in a balanced 4 × 4 Latin square sequence. Goats were fed the basal diet of SA followed by four shrub mixtures, three of which were composed of 35% shrubs and 65% SA, and the fourth shrubs alone. Daily feed intakes ($g/Wkg^{0.75}$/day) were: basal, 55.2; three mixtures of shrubs and SA, 47.9; and all-shrub, 18.5. Lignin:ADF ratio was highest in the all-shrub mixture. Estimates of apparent digestibility of the feed mixtures by four methods: fecal nitrogen index FNI, ratio techniques; acid detergent lignin (ADL) and insoluble ash (AD-IA), and two-stage *in vitro* digestibility using inoculum from an alfalfa-fed cow, were compared to total fecal collection (*in vivo*) values. The four methods gave comparable estimates to the *in vivo* digestion coefficients for SA, but none reliably estimated the shrub-containing feeds. The *in vitro* technique under-estimated digestibilities of these diets, while the other three over-estimated them. *In vitro* digestibility of shrub diet samples collected by browsing goats were significantly ($P < 0.005$) higher (49% vs. 45%) when the diet of the donor goat

contained 65% shrubs than when it was alfalfa alone. Discrepancies between *in vivo* and marker methods were related to apparently higher recoveries in the feces than the feed (e.g., ADL, 109.4 ± 1.2% and AD-IA, 223.4 ± 8.9%). All fecal samples contained a considerable amount of soil silica. Lambourne's equation was inappropriate for shrub diets, as fecal nitrogen of dietary origin (AD-N) and of endogenous secretions plus microbial residue (EEMR) from the shrub mixtures had higher recoveries (e.g., all-shrub feed, 51% and 65%) than SA (5% and 28%). Our results indicate that the *in vitro* technique is useful if an appropriate source of inoculum is used.

1166. Sidahmed, Ahmed E., James G. Morris, and Steven R. Radosevich. 1980. **Digestibility and residence time of browse and herbaceous species in the alimentary tract of Spanish goats (Abstract).** *In:* Proc. 33rd Ann. Mtng., Soc. Range Manage., San Diego, CA.

Abstract: Digestibility and residence times in the gut of hand-harvested dried browse mixtures were measured using four Spanish wether goats in metabolism cages. Goats were initially fed a basal diet of chopped sudan grass and alfalfa hays (35:30), which was followed by one of four mixtures of shrubs. Three mixtures were 35% sudan, 30% alfalfa, and 35% shrubs (chamise, scrub oak, and eastwood manzanita), while the fourth was shrubs alone. Organic matter digestibility (OMD) of the basal, all-shrub, and three sudan-alfalfa-shrub mixtures was 60%, 45%, and 56%, respectively. OMD of the shrub combinations alone in the mixed diets was calculated by simultaneous equations and ranged from 47% to 49%. The mean N balance of the goats on all diets containing sudan and alfalfa were positive, whereas on the all-shrub diet, it was negative. Following the change from the basal to shrub diets, the feces were examined microhistologically. Changes in percentage (Y) of shrub species in the feces with time (S days) followed negative exponential relationships $Y = A\ (1\text{-}BE^{-ex})$. The equilibrium time (95% of maximum discernibility) varied both with goats and feed mixtures. For the shrub diet alone, it was 12, 14, and 15 days for scrub oak, chamise, and manzanita, respectively. For some of the other combinations, equilibrium time was attained in 4-5 days. The disappearance times (<5% discernibility) for sudan and alfalfa were 13 and 15 days, respectively. When the diet contained herbaceous species, the microhistological technique gave a consistent over-estimation of all shrub components (despite the use of appropriate correction factors). After the disappearance time of sudan and alfalfa, shrub species were underestimated by the microhistological technique. Our data indicate that the microhistological technique used on fecal material has limitations in its ability to quantitatively predict dietary composition.

1167. Sidahmed, Ahmed E. 1981. **Selection, intake and utilization of browse by goats.** Ph.D. Dissertation, Univ. Calif. Davis. 176 pp.

Abstract: The broad objective of the studies reported in this thesis was to develop data on the use of goats as a tool in forest fuel management. Specific objectives included: selectivity and preference of goats, information on different procedures, techniques, and methodologies of measuring the performance of goats grazing chaparral; the contributions of the dominant shrub species to the energy and protein requirements of the goats; and the seasonal variations in the value of some key chaparral species with regards to intake and dietary composition.

A series of grazing and digestion studies were conducted to investigate the selection and utilization of chaparral by Spanish goats. In the summer of 1977, a preliminary grazing trial was conducted on a 5-year regrowth stand in southern California with the following dominant shrub species: chamise, scrub oak, eastwood manzanita, and cupleaf ceanothus. Daily dry matter intake by goat wethers of 30 kg body weight (W) was 61 $g/W^{.75}$. Browse preference was directed (about 80%) toward scrub oak and chamise. Grasses and forbs constituted most of the remainder of the diets and accounted for 50% of the variations in *in vitro* dry matter digestibility (IVDMD).

For the indoor digestion experiment, hand-harvested mixtures of dried leaves and twigs of chamise, scrub oak, and manzanita (from a 3-year regrowth stand at Hopland) were compounded in varied proportions with or without a basal feed of sudangrass and alfalfa hay. The basal feed, three herbaceous-shrub mixtures, and an all-shrub mixture were fed to goat wethers housed in cages. All feeds, except the 100% shrub mix, provided goats with maintenance intake and had protein/energy ratios (% DE supplied by digestible protein) of 12% to 21%. When goats were fed the all-shrub diet, they had submaintenance energy intakes and negative nitrogen balances. The efficiency of cellulose digestion in shrubs was less than in herbaceous species that had lower lignin:ADF ratio.

Digestibility values estimated by four indirect methods (fecal nitrogen index, sulphuric lignin (ADL_S), acid detergent insoluble ash (ADIA) ratios, and the two-stage *in vitro* techniques) were compared to *in vivo* values. All methods overestimated digestibility of shrub-containing feeds except the *in vitro* method, which approximated *in vivo* when the donor goat was fed 65% shrub diet.

Daily fecal samples collected in the digestion trials were used to estimate dietary composition by the microhistological technique. The precision of quantifying dietary composition from either the percentage of fecal epidermal fractions, or by a model using the passage of cell wall contents (CWC) through the gut, was evaluated by the ratio of actual (A) to estimated (Q) or predicted ($\hat{P}$) values. Whereas Q values were estimated at steady state, $\hat{P}$ values were computed from nonlinear relationships of CWC and cell wall digestibility of species, feces, and of potentially digestible portions ($\hat{S}$) of each species in the diet. Different methods of improving the analytical correction factors were compared. Herbaceous plant species were consistently underestimated by A/Q ratios, whereas browse species were overestimated in herbaceous-shrub mixtures. These ratios were closer to unity in the all-shrub diet. The precision of the technique was improved by $A/\hat{P}$ ratios in the herbaceous-shrub mixtures. When the model to estimate $\hat{P}$ was tested for predicting the composition of esophageal samples (A') from feces of goats grazing browse-dominated plots, the model was unreliable and generated inferior precision ratios compared to A'/Q ratios.

The effect of season on utilization of one year regrowth of chaparral by goats was investigated during spring, summer, and fall 1979. Preference was highly directed towards oak (>50%) and chamise (>30%) in all seasons. Manzanita and ceanothus were equally discriminated against. Correlation of selectivity (% in diet) and availability indicated that goats may be generalist but select between dominant species. Tannins were at low concentrations (2%) and did not appear to affect utilization. Recently burnt chaparral provided a maintenance diet for Spanish goats during spring and summer only.

In another four plots, vegetation was manipulated to either two or three of the following shrubs: oak (scrub oak and live oak), chamise, and manzanita. Intake suggested that Spanish goats obtain a maintenance diet from low quality vegetation by selection. They exhibited a specialized behavior for oak and chamise when resources permitted (>565 kg DM/ha), particularly of the most palatable shrubs (oak). At low yield (190 to 400 kg DM/ha), goats were generalists and selectivity was directly associated with availability. Chamise was moderately palatable, while manzanita was rejected until oak and chamise were depleted of shoots. Results of step-wise regression analysis showed that over 50% of variations in selectivity of each shrub species was accounted for by the dietary variables IVOMD, N, NADC, $NADL_S$, and intake.

The model of functional response relationships of use (selectivity) and availability showed a better approximation to these data than relative preference index. Low selectivity-availability correlations (regardless of direction) were suggested to be indicative of

specialized strategies of selection from a mixture of palatable and unpalatable species.

1168. Sidahmed, Ahmed E., Steven C. Denham, James G. Morris, Ling J. Koong, and Steven R. Radosevich. 1981. **Precision of microhistological estimates of goats' diets from fecal analysis and cell wall passage through the gastrointestinal tract.** Pp. 201-204 *in:* Proc. West. Sect. Am. Soc. Anim. Sci., Vol. 32.
Abstract: Daily fecal samples collected from Spanish goat wethers fed herbaceous-shrub and all-shrub diets following a basal diet of Sudan grass and alfalfa were used to estimate dietary composition by the microhistological technique. The precision of quantifying dietary composition from either fecal epidermal fractions (Q) or by a model using the passage of cell wall contents (CWC) was evaluated as a ratio of actual (A) to estimated Q or predicted ($\hat{P}$) values. Analytical correlation factors for Q were derived from the comparison of actual weights of species fed and relative densities (% DM) of discernable fractions from ground nondigested (GND) or ground *in vitro* (96 hr) digested (GIVD) residues. Steady state Q values for the first period in the trial were calculated from best fit negative exponential or decay relationships. Also Q values were calculated as the mean of the 20th day of all experimental periods. Parameter $\hat{P}$ was estimated as a nonlinear function of CWC and cell wall digestibilities of species, feeds, feces, and of potentially digestible portions of each species in the diet. Herbaceous plants were consistently underestimated by A/Q ratios in herbaceous-shrub mixtures, whereas browse species were overestimated. A/Q ratios were closer to unity in the all-shrub diet. A/Q ratios based on GND were significantly different ($P < .001$) from those based on GIVD. The precision of the technique was improved by A/P ratios in the herbaceous-shrub mixtures. When the model to estimate P was tested for predicting composition of esophageal samples (A') from feces of goats grazing browse-dominated plots, the model was unreliable and generated inferior precision ratios compared to A'/Q ratios, except for one species. However, this approach is inexpensive and rapid for ranking the most important browse species in the diet.

1169. Sidahmed, Ahmed E., James G. Morris, Ling J. Koong, and Steven R. Radosevich. 1981. **Contribution of mixtures of three chaparral shrubs to the protein and energy requirements of Spanish goats.** J. Anim. Sci. 53(5):1391-1400.
Abstract: Hand-harvested dry mixtures of chaparral shrubs (chamise, scrub oak, and manzanita) with or without a basal diet of sudan grass and alfalfa hay (SA) were fed to Spanish goat wethers in a 4 × 4 Latin square sequence. Feed intake (grams/kilogram body weight$^{.75}$/day) with each diet was: SA (fed initially) 55.2; mixtures of three shrub species and SA, 47.9; and shrubs alone, 18.5. Protein/energy (P/E) values (measured as percentage of digestible energy supplied by digestible protein) were 21% for the basal diet (SA) and 13%, 12%, and 14% for the three mixtures of shrubs and SA (diets A, B, and C). Diet D (all shrubs) had a negative P/E value, and goats fed this diet had negative N balances. No differences in *in vivo* digestibility were found between animals or periods, but means for dry matter digestibility of feeds, crude protein, and all fiber components were different ($P < .005$). Digestion of Diet D, which had the highest lignin to acid detergent fiber ratio, was lower ($P < .01$) than digestion of diets A, B, and C for most nutrients. Predicted digestibilities of feeds determined by four methods– 1) fecal N index (FNI); 2) and 3) ratio techniques, sulphuric lignin (ADL_S) and acid detergent insoluble ash (ADF-IA); and 4) *in vitro*– were compared to *in vivo* values. Whereas *in vitro* underestimated digestibilities of shrub-containing diets, the other three methods overestimated them. *In vitro* digestibilities of shrub diet samples collected by browsing goats were higher ($P < .005$) when donor goats were fed a 65% shrub diet than when they were fed a 100% alfalfa diet. Discrepancies between *in vivo* and markers (FNI, ADL_S, ADF-IA) were due to greater recoveries of ADL_S and ADF-IA in feces than in feeds. All fecal samples contained a considerable amount of soil silica. FNI appears inappropriate for estimating digestibility of shrub diets. The *in vivo* technique is useful if an appropriate source of inoculum is used.

1170. Sidahmed, Ahmed E., James G. Morris, Steven R. Radosevich, and Ling J. Koong. 1983. **Seasonal changes in composition and intake of chaparral by Spanish goats.** Anim. Feed Sci. and Tech. 8:47-61.
Abstract: Seasonal changes in utilization of one-year regrowth of chaparral vegetation by Spanish goats were investigated. The dominant shrub species were: oak (*Quercus dumosa* and *Q. wislizenii*), chamise, manzanita (*Arctostaphylos glandulosa*), and ceanothus (*Ceanothus cuneatus* and *C. foliosus*). Esophageal and fecal samples were obtained during the spring, summer, and autumn seasons of 1979. Mean daily temperatures for the three seasons were 19, 18, and 12°C, respectively. Winter sampling was restricted by cold weather at the 985-m elevation site. Cover was measured from ten permanent transects. Preference of Spanish goats was highly directed towards oak (>50%) and chamise (>30%) in all seasons. Correlation of selective (percentage botanical composition in the diet) and available data indicated that goats may be generalist in their feeding strategies, but display some sort of specialized behavior in selecting between the most dominant species. The observation that selection of herbaceous vegetation was restricted by availability conforms with the recent classification of goats as adaptive mixed feeders rather than browsers. Daily feed intake (g DM/kg BW$^{0.75}$) was calculated by dividing fecal residue by (100 - digestibility *in vitro*). Intake values were equivalent to maintenance requirements during spring (60 g) and summer (57 g). However, autumn chaparral provided sub-maintenance intake levels (36 g). Condensed tannins (ADF-NAD), estimated as the difference between acid detergent fiber (ADF) and sequential acid detergent residue of neutral detergent residue (NAD), were variable in the clipped shrub samples but low in all dietary samples (2.1 ± 1.8%). The low levels of tannins did not appear to be affecting the utilization of this browse. Predictive equations for intake (DMI) and digestibility *in vitro* (IVOMD) were derived from step-wise regression analysis using the following independent variables: cell wall content (CWC), NAD, cellulose (NADC), NAD sulphuric acid insoluble lignin ($NADL_S$), hemicellulose (NADHC), lignin: ADF-NAD tannins, ash and nitrogen (N). The equation for intake was: DMI (g DM/kg BW$^{0.75}$) = -25.67 + 1.80 OMD ($n = 56$, Syx = 17.72, r = 0.59, $P < 0.005$), while digestibility (%) was predicted as OMD = 56.98 - 0.46 CWC - 0.45 $NADL_S$ + .065 N + 0.09 DMI ($n = 56$, Syx = 2.77, r = 0.88, $P < 0.005$). It is concluded that recently-burnt chaparral vegetation would provide a maintenance browse for Spanish goats during the spring and summer seasons only.

1171. Snowder, Gary D. 1992. **Genetics of wool production.** Pp. 13-20 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: The author summarizes improvements in wool production within the last two centuries that have been based on our understanding of genetics and selection. Wool characteristics of North American breeds are compared to Australian Merino sheep. A discussion on directions for future wool quality improvement in the U.S. includes selection and genetic parameters of wool traits, inheritance of undesirable wool characteristics, and genetic engineering. The author notes that wool characteristics are moderately to highly heritable and will respond to selection. In breeds where wool is relatively unimportant economically, selection for increased fleece weight should remain a low priority. Improvement programs for wool producing breeds should continue to select for increased wool production while maintaining fiber diameter. Selection for improving fiber diameter is expensive and should only be considered when the mean fiber diameter of a flock is

close to an economic threshold for wool pricing that will result in a significant increase in value.

1172. Snowder, Gary D. 1992. **Economics of wool production.** Pp. 36-44 *in:* Wool Production School, Hopland Field Station, Univ. Calif., Ukiah and Hopland, CA, Apr. 3-5.
Abstract: Wool revenue has been estimated to contribute 25 - 30% of total income for U.S. producers on a per ewe basis. While wool prices in the U.S. are predominantly influenced by fluctuating world markets, U.S. producers can control certain factors during production and handling that impact the value of the individual's wool clip. Price differentials for diameter, yield, skirting, and classing of wools are significant and should be capitalized on by all producers. Economic incentives for improving quality by management, breeding, and packaging are substantial. Impacts of the National Wool Act of 1954, resulting in incentive payments to producers, are discussed.


Robert M. Timm

Assistant shepherd Gil Dow weighs newborn lamb, Main Barn, Winter 1990

1173. Snowder, G. D., C. J. Lupton, J. M. Shelton, R. W. Kott, G. Eric Bradford, Martin R. Dally, A. D. Knight, H. A. Glimp, P. J. Burfening, and P. V. Thompson. 1997. **Comparison of U.S. fine-wool breeds and Australian Merino F1 crosses: I. Wool characteristics and body weight.** Sheep and Goat Res. J. 13:108-115.
Abstract: This study investigated the effects of infusing genes from two dissimilar Australian Merino types [fine-wool (FWM) and strong-wool (SWM)] into different U.S. fine-wool flocks on wool characteristics of resulting first cross (F1) ewes. The F1 ewes were the offspring from U.S. fine-wool ewes in different flocks located in four states (CA, ID, MT, TX) mated naturally or artificially to one of three ram types: FWM, SWM or Texas Rambouillet (RAMB). Identical six rams per sire breed were used to produce the F1 ewes (FWM, SWM and RAMB, respectively) for evaluation of body weight (BW) and wool characteristics at one and two years of age. Body weights were heaviest for ewes sired by RAMB compared with SWM and FWM ewes ($P < 0.05$). Fleece weight, staple length and yield (Y) were significantly increased ($P < 0.05$) by crossbreeding Australian Merino types on U.S. fine-wool ewes. Fleece weights at one and two years of age were greatest for SWM cross ewes ($P < 0.05$). Fiber diameters were 0.5 μm finer in FWM ewes compared to RAMB ewes. Variability of fiber diameters was lower for RAMB ewes than FWM and SWM ewes ($P < 0.05$). Subjective scores for wool face covering and belly wool covering were not very different among the three groups of ewes. However, subjective scores for quantity of skin folds were higher for FWM and SWM ewes compared with RAMB ewes ($P < 0.05$). In conclusion, wool production in U.S. fine-wool breeds can be improved by crossbreeding to selected Australian Merino rams. However, a decision to use this approach should also consider other production parameters.

1174. Snowder, G. D., J. M. Shelton, V. M. Thomas, R. W. Kott, Martin R. Dally, G. Eric Bradford, A. D. Knight, T. D. Willingham, Hudson A. Glimp, C. J. Lupton, and H. Sakul. 1997. **Comparison of U.S. fine-wool and Australian Merino F1 crosses: II. Growth and carcass characteristics.** Sheep and Goat Res. J. 13:116-121.
Abstract: This study investigated the effects of incorporating genes of two dissimilar Australian Merino types, fine-wool (FWM) and strong-wool (SWM), into different U.S. fine-wool flocks on growth and carcass characteristics of first cross (F1) wether lambs. The F1 wethers were offspring of U.S. fine-wool ewes in four different flocks crossed to one of three ram types: 1) FWM; 2) SWM; or 3) Rambouillet (RAMB). Six rams per sire type were used to produce the F1 lambs. Growth rate of ewe and wether lambs ($n = 1391$) was measured from birth to weaning. Wethers ($n = 355$) were slaughtered at approximately 52 kg live weight. Carcass characteristics measured included: hot carcass weight, dressing percentage, leg conformation score, USDA Quality and Yield Grades, back fat depth, longissimus muscle area and percent kidney and pelvic (KP) fat. Statistical analyses were performed for a nested split-plot design. Lambs sired by RAMB rams grew faster than FWM- and SWM-sired lambs ($P < 0.05$). Carcasses from RAMB-sired lambs were the most desirable for leg confirmation score, longissimus muscle area, back fat depth and yield grade. Carcasses from lambs sired by FWM rams had higher percentage KP fat and thicker measures of back fat depth than those sired by SWM and RAMB rams ($P < 0.05$). Sire breed did not influence dressing percent or quality grade ($P > 0.10$). It is suggested that Australian fine-wool Merino-cross lambs should be slaughtered at live weights lighter than RAMB-sired lambs to be comparable in fat characteristics to the more desirable RAMB carcasses. Generally, the characteristics of the RAMB-sired lamb carcasses were superior to Merino-sired carcasses.

1175. Snowder, G. D., J. M. Shelton, V. M. Thomas, R. W. Kott, G. Eric Bradford, C. J. Lupton, Martin R. Dally, A. D. Knight, T. D. Willingham, Hudson A. Glimp, and P. V. Thompson. 1997. **Comparison of U.S. fine-wool and Australian Merino F1 crosses: III. Lamb production.** Sheep and Goat Res. J. 13:122-126.
Abstract: Sheep producers in the United States have expressed interest in the inclusion of Australian Merino sheep in crossbreeding programs with U.S. fine-wool sheep to improve fleece characteristics. The impact on reproduction of the Australian Merino in a cross-breeding program is unknown. Therefore, a cooperative multi-institution research project was initiated to evaluate the reproductive performance of Australian Merino crossbred ewes. First cross (F1) ewes were produced by mating two strains (fine-wool or strong-wool) of Australian Merino rams to one of two U.S. western range breed ewes, Rambouillet or Targhee, at four different locations (ID, MT, TX, CA). Matings produced F1 lambs of one-half fine-wool Merino (FWM) or strong-wool Merino (SWM) and one-half Rambouillet or Targhee. Six Rambouillet rams were selected from flocks in Texas to produce control populations (RAMB). Reproduction was observed on F1 ewes at 2 years ($n = 596$) and at 3 years ($n = 540$) of age. Two-year-old RAMB-sired ewes had the highest overall fertility rates (average, 85%) compared with FWM (78%; $P = 0.08$) and SWM (79%; $P = 0.12$). At 3 years of age, fertility did not differ among sire breeds ($P > 0.10$); however, fertility

of SWM (87%) was lower compared with FWM (92%; P = 0.09) and RAMB ewes (92%; P = 0.12). The RAMB ewes had higher levels of prolificacy than FWM and SWM ewes. At 2 and 3 years of age, FWM and SWM ewes weaned litters of comparable weights (P > 0.10) but lighter than RAMB ewes (P < 0.05). Litter weights for RAMB ewes were 10 to 12% heavier than the Merino-cross ewes. Large phenotypic variations among and within genotypes suggest that genetic approaches be considered to increase lamb production. When U.S. producers are considering Australian Merinos for improving wool characteristics, they must also consider sire differences for reproductive traits or any economic gains in wool production could be offset by diminished lamb production.

1176. Spurlock, G. M., Donald T. Torell, B. McGowan, William C. Weir, and G. Eric Bradford. 1959. **Effect of vitamin D and of shearing on ewe lambs.** J. Anim. Sci. 18(4):1250-1254.
Abstract: Weanling ewe lambs on range forage were supplemented with different rations from July to December 2, 1957. Lambs were allotted within different ration groups so as to include three groups of lambs each representing a different shearing treatment. On December 2, half of each shearing treatment group was given 1 million I.U. of vitamin D in intramuscular injection. Weight gains were compared over the period of July 16, 1957 to April 29, 1958 and clean wool production over the period of May 5, 1957 to April 28, 1958. Lambs shorn in August and again in April showed a non-significant increase in weight gain (2.1 lb) but a significant (P < .01) increase in clean wool production (0.97 lb) compared to the group shorn in April alone. Shearing in March and reshearing in April was of no advantage compared to April shearing alone. Vitamin D injection tended to decrease gain (not significant) and significantly (P < .05) lowered clean wool production, by comparison with controls. Earlier supplementary rations showed no significant effect on weight gains over the total period but did significantly (P < .01) affect clean wool production. Neither vitamin D injection nor early shearing was of sufficient benefit to weanling ewe lambs to warrant use in one of the heaviest rainfall years on record in the Hopland area.

1177. Spurlock, G. M., Stanley P. Davis, and G. Eric Bradford. 1962. **Methods of estimating clean fleece production.** Calif. Agric. 16(5):12-13.
Abstract: Selecting sheep for wool production requires accurate method to determine the clean fiber content of fleeces. In a two-year experiment, the Neale "squeeze" machine was evaluated for use on California and Texas wools. While not as accurate as the side sample method, it was much easier, quicker, and less expensive. The animals can be rated in order of clean wool production more accurately than by grease weight, for high-shrinking wools. Rating of animals in this manner allows the breeder to choose those of higher productivity. The side sample method in most cases cannot be used by untrained personnel, while the squeeze machine can. In high rainfall areas and with breeding stock producing high-yielding fleeces, grease fleece weight may equal or surpass the squeeze machine in accuracy. The machine does not appear to be of sufficient accuracy to determine shrinkage of wools for sales purposes.

1178. Stansfield, W. D., G. Eric Bradford, C. Stormont, and R. L. Blackwell. 1964. **Blood groups and their associations with production and reproduction in sheep.** Genetics 50(6):1357-1367.
Abstract: Nine lamb-production traits, 13 yearling production traits, and four reproductive traits were analyzed for their association with sheep blood-group alleles at seven loci. Data on a total of 2,507 white-faced western range sheep from three environments, four years, and five genetic backgrounds were used. Gene frequency estimates are presented for each of 15 inbred lines and for five noninbred populations. The 4,877 comparisons of blood groups with production traits failed to show significant associations which were consistent from year to year or from breed to breed for any locus or trait. Heterozygosity at one or more of seven loci (*A*, *C*, *D*, *M*, *R*, *I*, or *X*) appeared to be correlated with higher weaning weights and possibly with a more desirable meat-type lamb conformation. Some evidence indicated that blood groups were contributing to the genetic variance of yearling records also, but the magnitude of such contributions was too small to be recognized consistently in individual comparisons. Offspring from parents of divergent B-factor compositions were equally as productive as the offspring from parents of more uniform B-factor compositions. No predictable genotype-environment interactions were detected. Different background genotypes had no consistent effect on the associations between the blood groups and production traits. Maternal heterozygosity at the *A*, *D*, *R*, and *X* loci was not significantly associated with twinning percentages, percentage of dry ewes, or with survival of lambs at birth or from birth to weaning. Offspring with heterozygous blood-group genotypes at the *A*, *D*, *R*, and *X* loci appeared to possess no special survival advantage over the other blood-group genotypes. Maternal-fetal blood factor differences were not found to contribute to lamb mortality. Maternal blood groups did not appear to be associated with resistance to vibriosis.

1179. Tomlinson, Kim A., Edward O. Price, and Donald T. Torell. 1982. **Responses of tranquilized post-partum ewes to alien lambs.** Appl. Anim. Ethol. 8:109-117.
Abstract: The objective of this study was to determine the effect of tranquilization on the responses of ewes to alien lambs substituted for own lambs 48-72 hours after parturition. Eleven ewes whose young had been taken away, and nine ewes with a lamb of their own, were penned with alien lambs following a single injection of the tranquilizer perphenazine. Seventeen control ewes, including 15 whose only young had been taken away, were also exposed to alien lambs after receiving placebo injections of normal saline. The responses of these ewes to the alien lambs were studied over a four-day period. All 10 tranquilized ewes exposed to a single alien lamb without their own young present readily accepted the strange offspring. All of the tranquilized ewes accompanied by one of their own offspring, and a single ewe that was given an alien set of twins in place of her own single lamb, subsequently rejected the strange young. Six of 15 control ewes, with own young removed, accepted alien lambs. The remaining 11 control ewes rejected alien lambs. The success of fostering appeared to be positively related to the persistence of suckling attempts by the lamb, and inversely related to the aggressiveness of the ewe. Tranquilization under the conditions employed can be an efficient technique for fostering single alien lambs on postpartum ewes that have lost their own lambs, but does not facilitate fostering on ewes with their own young present.

1180. Torell, Donald T., and William C. Weir. 1952. **Self feeding cottonseed meal and salt to ewes under range conditions (Abstract).** Proc. West. Sect. Am. Soc. Anim. Prod. XXI.
Abstract: A feeding trial to determine the desirability of self-feeding cottonseed meal to ewes under range conditions was begun at Hopland in 1951. Granulated hay salt, mixed with the cottonseed meal in a 1:3 ratio, was used as a consumption-limiting agent. Because range feed became limited during late fall, sheep were supplemented with 1 lb alfalfa hay/head/day beginning November 25. Consumption of the cottonseed meal supplement ranged from 0.1 lb /head/day on October 1, when the trial was initiated, to a maximum of 0.35 lb/head/ day on January 15, during lambing. There was a decline in consumption to 0.07 lb/head/day by March 1. The increase to 0.35 lb was probably caused by leaching of the dry range feed due to heavy rainfall and the advancing pregnancy and lambing of the ewes. The heaviest lambing occurred between December 23 and January 1. The decrease in consumption between January 20 and March 2 may be attributed to the increasing amount of green feed available even though scant and washy. After March 2,

these ewes and their lambs were turned out with the other ranch ewes and received no feed supplement until shearing and weaning time. Weaning percentage in the self-fed group was 78%, as compared to 58% in the control group. Weaning weights of the lambs on the high salt concentration averaged 5.7 lbs more than those in the control group. Difference in average ewe weights during the feeding period was not significant.

1181. Torell, Donald T. 1954. **An esophageal fistula for animal nutrition studies.** J. Anim. Sci. 13(4):878-884.
Abstract: The most accurate method of determining chemical composition and palatability of forage to livestock is to use the animals itself as the collection agent. To accomplish this, a series of trials with sheep resulted in the preparation of an esophageal fistula which would enable the animal to drink and eat normally, but which could be opened allowing the forage eaten to be diverted through the fistula into a collection bag. In this way, it is possible to collect fresh forage before it has undergone any chemical changes in the digestive system other than those occurring in the animal's mouth. This paper describes a series of trials in which different methods of surgically creating the fistula were investigated. Comments on the care and use of fistulated sheep are included, including an improved method for closing the fistula at times when samples are not being collected.

1182. Torell, Donald T., and William C. Weir. 1954. **Salt concentrate mixtures.** Calif. Agric. 8(1):3-4.
Abstract: Trials are described in which sheep on range were provided feed supplements during summer and fall, when available forage is often lacking in protein, phosphorus, and carotene. It was determined that the use of self-fed salt-concentrate mixtures to limit consumption of supplements while maintaining range sheep on a good level of nutrition. Trials at Hopland during 1951-1953 involved supplementing ewes on range with 1 lb alfalfa/head/day in addition to providing self-feeding of a cottonseed meal-salt mixtures, to which ground barley was added in the latter years to provide additional carbohydrates. Consumption data for these supplements, mixed in various proportions, is reported. It is concluded that consumption rate of supplemental feeds is affected by a number of factors, including climatic conditions, the ewes' preferences for feeds, the nutrient content of natural range feeds, and the lambing status of the ewes. Consumption may be limited by the use of granulated salt in the supplement and– if not completely controlled– at least influenced by increasing or decreasing the percentage of salt in accordance with existing conditions and desired level of supplementation. Self-feeding of salt concentrate mixtures may be used to maintain range animals on the desired plane of nutrition with considerably less labor than if daily hand feeding were practiced.

1183. Torell, Donald T., and William C. Weir. 1954. **Supplemental feed for ewe lambs.** Calif. Agric. 8(12):8-9, 16.
Abstract: Two of the problems facing the rancher who grows out his own replacement ewes on California's annual range are closely related: 1) the inevitable loss of weight that occurs after weaning in the spring and the following February– the period when the nutritive value of the annual range forage is low– and 2) the increase infestation of parasites in the thin, weakened lambs that occurs when they eat green feed available after the fall rains begin. Studies have shown that these problems can be minimized by supplementing weaned lambs. This paper reports on the economic feasibility of supplementation. Two groups of 86 weaned ewe lambs were rotated between two similar pastures every 28 days beginning in June, for a 190-day period. One group was unsupplemented, the other was self-fed a supplement of salt, cottonseed meal, and barley. Both groups received anti-parasite drugs. The influence of supplemental feed was most striking in lamb weights. In late September, the supplemented group had gained an average of 9 lbs/lamb, while the control group had lost an average of 6 lbs. During the trial only 4 of the self-fed lambs died, while 13 losses occurred in the unsupplemented group, presumably from parasite infection. Supplementing cost $2.85/sheep for the 190-day trial. This cost was more than offset by higher wool production (an additional 1.5 lbs/lamb) and by the survival of 11% more lambs in the supplemented group. The cost of feeding replacement ewes during the dry summer months and the early winter was offset by increased wool production, body weight, and number of sheep saved.

A. H. Murphy

Left to right: Animal Science specialist Don Torell and shepherds Lee Humphrey and Richard Rainoldi weigh lambs, Main Barn, Spring 1965

1184. Torell, Donald T., D. W. Cassard, William C. Weir, and J. F. Wilson. 1956. **Gains of two types of lambs.** Calif. Agric. 10(9):11.
Abstract: This study was conducted in order to determine which of two sheep breeds, Suffolk and Corriedale, produce heavier lambs at weaning. During a 3-year study, it was found that Suffolk-sired lambs from grade Corriedale ewes gained faster than Corriedale-sired lambs at Hopland. Male lambs were heavier than females within their own breed. Suffolk-sired wether lambs and ewe lambs weighted an average of 8.0 lbs and 6.5 lbs more than Corriedales at weaning, respectively. Suffolk wethers averaged 5.5 lbs more than Suffolk ewe lambs, and Corriedale wethers averaged 3.0 lbs more than ewe lambs of the same breeding. There are factors other than lamb weights to be considered when deciding which breed fits into any given sheep operation. These include comparative initial cost of rams (Corriedale rams were about half the price of Suffolks), breeding life of the rams (about 6 years for Corriedales, vs. about 2-3 years for Suffolks), and whether the operation raises its own replacements or buys them from an outside source.

1185. Torell, Donald T., M. T. Clegg, William C. Weir, and H. H. Cole. 1956. **Estrus and conception post partum in sheep.** Proc. West. Sect. Am. Soc. Anim. Prod. 7:LIV1-LIV4.
Abstract: A knowledge of post-partum heat and conception in sheep is important when studies of the reproduction system are contemplated. A study to observe the breeding habits of lactating ewes was initiated during the lambing season of 1953 and concluded after the lambing season of 1995 at Hopland. Thirty Rambouillet-Merino ewes were used; from one-half of these ewes the lambs were weaned within a day after birth. From the remaining half, half of the lambs were weaned on June 6 and the other half on July 14. Two Corriedale rams ran with the experimental ewes from December 10, 1953 to April 20, 1954. From April 20 on, from 4 to 25 rams ran with the ewes. Marking harnesses were used on the rams until April 20, and daily observations were made. During the second year, the weaning was reversed between the two groups of ewes. All of the ewes from which lambs were weaned at birth bred again post partum, whereas 33% of those which were nursing lambs did not breed.

Thus, it would appear that the effect of nursing on the post-partum estrus period varies with ewes. This is assuming that there were no contributing factors. When post-partum conception occurs among lactating ewes, however, there is no significant difference between time of conception in that group and in the non-lactating group.

1186. Torell, Donald T., C. F. Kelly, T. E. Bond, and William C. Weir. 1958. **Plastic shelters for new lambs.** Calif. Agric. 12(1): 8-9.
Abstract: Losses of range-born lambs, in some instances as high as 90%, have resulted from severe rainstorms during the lambing season on north coast sheep ranges. Conventional protective range shelters or barns usually are economically unfeasible because of high cost. An inexpensive, experimental polyethylene plastic shelter was tested at Hopland during the 1957 lambing period, and the percentage of lambs saved that season was highest since the field station was established in 1951. The experimental shelter had a light wood framework covered with both translucent and black plastic film. Only 50 man-hours of labor were needed for the construction job. There were no apparent differences in the behavior of animals under black or translucent film. However, on sunny warm days the thermal environment under the translucent film appeared to be too warm for the animals. Plastic manufacturers advise that translucent plastic loses most of its strength in one season whereas black film loses one-half of its strength in 10-15 years. It is recommended that the film be attached solidly to the framework wherever they touch and be protected from punches by sharp objects. When film is installed during wet weather it should be stretched tightly over the framework. In warm weather, sufficient slack should be allowed during installation to allow for contraction when the weather cools. Plastic should be installed only on calm days because considerable force is exerted by even the slightest air movement. Design details are illustrated.


Don Torell

Marshall Slater and Richard Rainoldi check newly-completed sheep shelter utilizing thin plastic roofing material, November 1966

1187. Torell, Donald T., C. F. Kelly, and Thayer Cleaver. 1959. **Plastic films for livestock shelters.** *In:* Proc. Am. Soc. Agric. Eng., Paper 59-835, Chicago, IL, Dec. 16-18. 6 pp.
Abstract: It has been shown that newborn lambs are much more likely to survive if they are provided shelter at night where they can have a chance to dry off and regain normal body heat. Nevertheless, to be acceptable to most ranchers, lambing shelters must be extremely cheap. This need for extreme economy led to the testing of several structural designs at Hopland. Plastic-covered buildings proved most successful in providing the maximum protection possible with minimum expenditures for labor and building. Such buildings were built at a cost of 7 to 10 cents per square foot of floor space. The plastic film lasted longer if a number of precautions were followed: buildings should not be located near trees, where falling branches can puncture the film; support poles must be firmly anchored to prevent wind from pulling the shelter from the ground; the framework and nailing strips should have rounded, smooth edges; adhesive should be applied wherever the plastic touches the framework; the film should be stretched taut if applied on cold days and loosely on warm days; and the film should be applied only on very still days. Costs for construction could be recovered by only 1.5 pounds extra gain per lamb, or saving a single extra lamb per 100 ewes, or by saving 10 to 15 pounds of hay per year per sheep. Illustrated construction designs are provided.

1188. Torell, Donald T., and William C. Weir. 1959. **The effect of rotational grazing on animal nutrition.** Proc. West. Sect. Am. Soc. Anim. Prod. 10:XL1-XL6.
Abstract: Changes in nutrient intake resulting from rotational grazing program were studied. Sheep grazed two types of pasture: improved range which had been seeded and fertilized, and unimproved native annual range. Each of these two areas was divided into 4 pastures and sheep were rotated among the pastures within the pasture type. Sampling was done with esophageal-fistulated sheep. Sampling areas, 30' × 30', were established in each pasture. Collections were taken in these areas with the fistulated sheep before the main flock entered the pastures. The collection areas were then opened to grazing until the end of the grazing period when another collection was made. Forage samples were analyzed chemically for protein, crude fiber, lignin, ether extract, and silica-free ash. The crude protein content of forage changed abruptly when sheep were moved from the grazed to the ungrazed pasture; because of growing season, forage protein usually increases until February and the decreases through the rest of the testing period. In most pastures there was a gradual decrease in crude protein while the sheep were in the pasture. The crude fiber content in 5 of the 6 grazing periods increased with grazing in the imported pastures. In contrast, a decrease in crude fiber occurred in all of the grazing periods in the unimproved pastures except the first period. The lignin fraction was erratic and ether extract showed no definite trend. Silica-free ash determination is meaningless without the use of a saliva tracer. Analyses indicated that the chemical composition of grazed forage changed when sheep were rotated between pastures. A change also occurred during the grazing period within a given pasture.

1189. Torell, Donald T., and William C. Weir. 1964. **Lamb growth after early weaning.** Calif. Agric. 18(10):5.
Abstract: Early weaning results in lower lamb weaning weights and grades. However, the differences are not large and might be compensated for by the increased total weight of lamb produced per acre by increasing the number of ewes on the ranch. Better use of pastures by the weanlings while ewes are carried on less desirable range is possible with early weaning.

1190. Torell, Donald T., and William C. Weir. 1964. **Feeding intervals in range supplementation of pregnant ewes.** Calif. Agric. 18(11):7-8.
Abstract: Supplementing pregnant ewes is commonly used to increase productivity. However, labor costs of frequent feedings often amounts to as much as the feed itself. A carefully controlled trial conducted at Hopland in winter 1962 is reported here. Eighty-four pregnant ewes were assigned to 3 groups: Group I received no supplement; Group II received 7 lbs of alfalfa pellets per head each Monday; and Group III received 1 lb of pellets per head per day for 3 days and 2 lbs per head on Monday and Friday. All ewes grazed the same pasture. The trial began on December 18 and ended on January

25 when all ewes had lambed. Those ewes supplemented only once weekly gained more weight, and did so without adverse effects, when supplemented once weekly as compared to 5 times weekly. Both supplemented groups gained more weight than the control ewes. Birth weights of lambs were not affected by supplementation. When ewes were fed the entire week's ration at one time, the feed was completely consumed in 2 to 3 days. With this feeding program, even the most timid ewes had an opportunity to eat, whereas, with the ewes supplemented daily, the weak, timid ewes stood back and did not try to eat. No pregnancy paralysis or ketosis was observed. Under more severe conditions when range feed is in critically short supply, weekly feeding of supplements might cause such trouble. These results only apply when reasonable amounts of range feed are available to pregnant ewes.

1191. Torell, Donald T., Richard A. Rainoldi, Loren W. Neubauer, and Ralph R. Parks. 1966. **Plywood sheep shelter.** Leaflet 186, Calif. Agric. Exper. Sta. and Extens. Service, Division of Agriculture, Univ. Calif.
Abstract: A low-cost shelter is described that can be placed on sheep bedding grounds to provide protection from wind and rain. It can save many lambs that might otherwise be lost during the first few months of their lives. Shelters are made of plywood-covered arched trusses, built in sections, and can be connected to form a shelter of any length desired. At the time of publication, materials costs were about 15 cents/square foot. Weathering tests indicate an expected life of perhaps 10 years. Instructions for construction and for locating the structure are included, along with construction diagrams.

1192. Torell, Donald T., R. M. Bredon, and B. Marshall. 1967. **Variation of esophageal fistula samples between animals and days on tropical grasslands.** J. Range Manage. 20(5):314-316.
Abstract: Twelve indigenous Sangra cattle fitted with esophageal fistulas were used to collect tropical forage on 7 different dates within a 10-day period. Chemical analyses for crude protein, crude fiber, ether extract, and ash were determined on each sample. Analysis of variance shoed no significant difference between animals for crude protein, crude fiber, and ether extract. There were significant differences between days for crude protein and ether extract but not for crude fiber. The number of animal-days needed for a 95% level of accuracy and to come within ±10% of the mean was 5.6 for crude protein and 28.7 for ether extract. Crude fiber would need 4.1 animal-days to come within ±5% of the mean. A depraved appetite for salt in the fistulated cattle and the subsequent consuming of slat-saturated soil appeared to be the cause of a significantly higher silica level in the feces of these steers as compared with non-fistulated steers. Fecal crude protein, crude fiber, and ether extract, when expressed on an ash-free basis, showed no significant differences between fistulated and non-fistulated steers. There were significant differences between animals and between days.

1193. Torell, Donald T., William C. Weir, G. Eric Bradford, and G. M. Spurlock. 1969. **Effects of time of shearing on wool and lamb production.** Calif. Agric. 23(11):16-18.
Abstract: The strength of wool fibers is affected by the health of the sheep when the wool is growing. Poor feed conditions, long cold stormy periods, and lambing and lactation stress may produce "breaks" in the wool or tender wool, caused by a temporary slowing of wool growth and reduction in fiber diameter. Fleece rot can also occur during long periods of wet weather. In the coastal areas of the western states, several of these conditions often coincide during December and January. Time of shearing will determine the position of the weakened area in the wool staple. If a weakened spot occurs midway in the length of the staple, the fleece will consist of two short lengths instead of one long fiber, the former considered less valuable by wool manufacturers. Time of shearing can affect both wool and lamb production and also ewe mortality. Shearing during seasons of the year other than spring and summer can increase lamb production and also produce stronger wool fibers. An experiment regarding timing of shearing was conducted at Hopland during from 1962 through 1966; treatment groups of ewes were shorn in either April, July, or December. Total amounts of grease wool production for April- and July-shorn sheep (31.4 and 35.0 lbs, respectively) were significantly different ($P < 0.01$) but neither was different from December-shorn sheep (33.6 lbs). There were no differences among treatments in average total number of lambs born per ewe bred; however, the December group lost fewer lambs so that the number of lambs weaned was significantly higher than in the other groups. December-shorn ewes in the first two years had fewer open ewes and more multiple births. It appeared that shearing was detrimental to ewe welfare at all dates, since ewe mortality was higher immediately after shearing than at other times. The number of deaths in both the July- and December-shorn groups was considerably higher than in the April group. Inclement weather in December, and nutritional stress in July, may have been contributing factors. In choosing the shearing date, sheepmen should try to select a season relatively free of wide fluctuations in temperature, should provide shelter where possible after shearing, and should keep freshly shorn ewes on a high plane of nutrition.

1194. Torell, Donald T., and William C. Weir. 1970. **Protein effects on weight, lambs born, and blood urea (Abstract).** P. 256 *in:* Proc. 62nd Ann. Mtng. Am. Soc. Anim. Sci.
Abstract: Three-hundred fifteen ewes, 1½ to 7 years of age, were allotted at random (stratified by age) into 6 treatments. Ewes grazed dry annual range pastures and received individual supplementation with 0, 90, 180, 270, 360, and 450 grams pelleted alfalfa hay 18 days prior to breeding and during the first 18 days of breeding. Adjusted average daily gain (g) during the 36-day period were: 0, 36, 39, 78, 111, and 100, respectively. At lambing, the number of lambs born per number of ewes bred (L/E) were: .98, 1.04, 1.05, 1.12, 1.30, and 1.27. Blood urea nitrogen (BUN) rates (mg %) at the start of breeding , after 18 days of supplementation, were: 8.3, 9.0, 10.2, 11.7, 12.8, and 13.7. The correlation coefficient (r) of supplemental nitrogen intake (SNI) and weight gain was .95; of SNI and BUN, .99; of SNI and L/E, .94. The (r) of BUN and weight was .96 and of BUN and L/E, .94.


Guy E. Connolly

Shepherd Lee Humphrey works with ewes in Main Barn, November 1973

1195. Torell, Donald T. 1971. **The strategic management of sheep.** Natl. Wool Grower 61(9):34-36.
Abstract: Various sheep management practices are listed and

described for consideration in strategically planning a profitable enterprise. Wool continues to be of value only because of the incentive payment; the authors believe that it is not a viable alternative to select for wool quality. Increased lamb production is highly dependent upon selecting the breeds most suited for the particular climate and feed conditions. Nutrition can play a large role in ovulation rate of sheep on California range, as shown by recent flushing trials. Great efficiencies of breeding in dry lots are discussed. Potential use of agricultural and industrial by-products as livestock feeds is discussed.

1196. Torell, Donald T., I. D. Hume, and William C. Weir. 1971. **Flushing ewes by supplementation, improved pasture or drylot (Abstract).** P. 246 *in:* Proc. 63rd Ann. Mtng. Am. Soc. Anim. Sci.
Abstract: Two experiments were conducted to determine the most efficient way of improving lambing performance of range ewes. In the first experiment, conducted in each of 4 years, 130 to 150 mature ewes were randomly allotted to 3 groups for 17 days prior to and 17 days during breeding. Group 1 (control) remained on dry annual range pasture; Group 2 ewes remained on range with Group 1 but were supplemented with 2.25 kg/head/week pelleted alfalfa hay, fed twice a week in individual pens; Group 3 ewes were fed in drylot 1.82 kg/head/day pelleted alfalfa hay. Mean lambing percentages (lambs born/ewe present at lambing × 100) were 99 (13.4% multiple births), 109 (21.% multiple births), and 127 (43.2% multiple births) in Groups 1, 2, and 3 respectively. In the second experiment, conducted in each of 2 years, an additional group of ewes (Group 4) grazed, over the flushing period, a subterranean clover-Hardinggrass pasture which had been mown prior to maturity. Lambing percentages were 110 (26.2% multiple births), 109 (18.3% multiple births), 139 (52.1% multiple births), and 138 (41.9% multiple births) in Groups 1, 2, 3, and 4, respectively. In both experiments lambing performance was improved by drylot feeding (Group 3) ($P < 0.001$), but not by supplementation of the range ewes (Group 2). In the second experiment access to good quality pasture (Group 4) also resulted in improved lambing performance ($P < 0.01$).

1197. Torell, Donald T., William C. Weir, and I. D. Hume. 1971. **Effect of protein and energy on lambing performance (Abstract).** P. 301 *in:* Proc. 63rd Ann. Mtng. Am. Soc. Anim. Sci.
Abstract: Two experiments were conducted to study the effect on subsequent lambing performance of varying levels of protein and energy in the diet of range ewes immediately prior to and during breeding. In 1968, 408 ewes grazing dry annual range pasture were fed in drylot 0.91, 1.27, 1.63, or 2.00 kg/day alfalfa wafers, and except at the highest level of alfalfa, either 0, 0.27, or 0.45 kg/day barley for 20 days prior to and 20 days during breeding. Nitrogen intake varied from 32 to 72 g/day and D.E. intake from 2.0 to 4.4 megcal/day. Lambing percentage (lambs born/ewe present at lambing × 100) increased from 108 (7.7% multiple births) for ewes fed 0.91 kg/day alfalfa to 167 (63.4% multiple births) for those fed 1.27 kg alfalfa and 0.45 kg barley/day (53 g N and 4.4 megcal D.E./day) ($P < .01$). In 1969, 306 similar ewes were fed 0.91 kg pelleted oat hay supplemented with 0, 0.27, or 0.45 kg barley and/or 0, 0.27, or 0.45 kg CSM/day. Nitrogen intake varied from 10 to 42 gm/day, and D.E. intake from 1.9 to 4.5 megcal/day. Lambing percentage increased from 110 (26.9% multiple births) on the basal ration to 139 (59.3% multiple births) on the basal ration plus 0.45 kg barley and 0.45 kg CSM/day (42 g N and 4.5 megcal D.E./day) ($P < .05$). Within the range of intakes used in these experiments, increased levels of both protein and energy were necessary for maximum lambing performance.

1198. Torell, Donald T., William C. Weir, and I. D. Hume. 1971. **Range supplementation of weaned lambs with coated urea (Abstract).** P. 301 *in:* Proc. 63rd Ann. Mtng. Am. Soc. Anim. Sci.
Abstract: One-hundred forty-five weaned lambs (average weight 35 kg) were divided at random into 10 groups. All lambs grazed a common dry annual range pasture, but they were individually penned 3 times a week and supplemented with 0 to 14.7 g N/feeding. Group 1 received no supplement. The remaining groups received, at each feeding, 100 g basal supplement (60% alfalfa pellets, 30% CSM, 10% molasses) and either 0 (Group 2), 4.8 g (Group 3), 9.5 g (Group 4), 14.3 g (Group 5), 19.0 g (Group 6), or 23.8 g (Group 7) coated urea; or 43 g (Group 8), 128 g (Group 9), or 213 g (Group 10) additional basal supplement. The lambs were weighed at the end of four 28-day periods. In each period, blood samples for blood urea nitrogen (BUN) analyses were taken at 24, 48, and 72 hours after supplementation. Adjusted average daily gains (ADG) (g) were 0 (Group 1), 22 (Group 2), 13 (Group 3), 19 (Group 4), 24 (Group 5), 13 (Group 6), 11 (Group 7), 29 (Group 8), 34 (Group 9), and 43 (Group 10). For the alfalfa groups, (1, 2, 8, 9, and 10) the correlation (*r*) between BUN and adjusted ADG was 0.94 (24 hr), 0.79 (48 hr), and 0.69 (72 hr); between BUN and supplemental nitrogen intake (SNI) 0.95 (24 hr), 0.78 (48 hr), and 0.73 (72 hr); and between SNI and ADG 0.97. For the coated urea groups (2, 3, 4, 5, 6, and 7) *r* between BUN and ADG was -.54 (24 hr), -.42 (48 hr), and -.15 (72 hr); between BUN and SNI 0.24 (24 hr), 0.60 (48 hr), and -.10 (72 hr); and between SNI and ADG 0.11. The negative correlation between BUN and ADG for coated urea indicates that the urea was available in the rumen but was not efficiently utilized by the microorganisms, possibly because energy was limited.

Guy E. Connolly

Automated lamb feeder at Nutrition Barn, March 1974

1199. Torell, Donald T. 1972. **Adding formalin to milk helps in raising orphan lambs.** Calif. Agric. 26(12):8-10.
Abstract: Many newborn orphaned lamb die because ranchers cannot easily afford to take the time required to keep nursing equipment clean. Adding an agent to lamb milk replacer that would control bacterial growth could eliminated the necessity of daily washing of equipment and would make orphan-lamb raising a more profitable operation. In these trials, the effectiveness of adding very small amounts of formalin to milk were shown effective in controlling bacterial growth while not adversely affecting lambs. Laboratory trials demonstrated that 1 ml formalin per gallon of milk (1:3800 ratio) was sufficient, at barn temperatures, to keep bacterial growth in milk to a minimum and yet allow good milk consumption and lamb growth, cleaning nursing equipment only weekly. In pilot lamb trials, lambs consumed milk with 5 times as much formalin (1:800) as was needed to prevent bacterial growth for a 7-day period. In a lamb performance trial, two groups of orphaned lambs were allowed to self-feed on either control milk replacer (and equipment was cleaned daily), while two other groups were given milk replacer including 1 part formalin in 800 parts milk (with equipment cleaned only weekly). Consumption was similar in treatment and control groups. There was no significant difference in lamb performance.

Photographs and diagrams of lamb nursing system equipment is included.

1200. Torell, Donald T., I. D. Hume, and William C. Weir. 1972. **Effect of level of protein and energy during flushing on lambing performance of range ewes.** J. Anim. Sci. 34(3):479-482.
Abstract: Two experiments were conducted to study the effect on subsequent lambing performance of varying levels of protein and energy in the diet of range ewes immediately prior to and during breeding. In the first experiment, lambing percentage (lambs born × 100/ewe present at lambing) increased from 102% for ewes receiving 33 g N and 2.0 Mcal DE/day to 166% for those receiving 53 g N and 4.4 Mcal DE/day ($P < .001$). In the second experiment, lambing percentages increased from 107% for ewes receiving 10 g N and 1.9 Mcal DE/day to 139% for those receiving 46 g N and 4.6 Mcal DE/day ($P < .05$). Multiple regression analysis was used to examine effect of level of protein and level of energy in the diet during flushing on lamb performance. In the first experiment, 7% of the regression sum of squares was due to protein, 61% to energy, and 32% to the joint effort of protein and energy. In the second experiment, the contributions to the sum of squares due to regression were 21% (protein), 35% (energy), and 44% (joint effect protein and energy). In both experiments, the relative importance of protein alone and energy alone was inversely related to the amount of each supplied by the basal ration.

1201. Torell, Donald T., I. D. Hume, and William C. Weir. 1972. **Biuret as a nitrogen supplement for flushing range ewes.** J. Anim. Sci. 35(3):606-610.
Abstract: The ability of ruminal microorganisms to degrade non-protein nitrogen compounds to ammonia and to use this ammonia for the synthesis of their own protein has been previously demonstrated. Urea has commonly been used as a nitrogen source, but its rapid rate of hydrolysis in the rumen is a serious disadvantage. This study examined an alternative to urea– its condensation product, biuret, which is degraded in the rumen at a much lower rate. Three experiments were conducted at Hopland to evaluate biuret as a nitrogen source for flushing range ewes. The lack of response in lambing performance in the first experiment was evidently due to the low total nitrogen intake of the ewes. In the second experiment, biuret was added to alfalfa to provide a supplemental nitrogen intake of 24 g/ewe/day, and lambing percentage was improved by 26.3% ($P < .05$). It was concluded that, provided the total nitrogen intake of the ewes during flushing was above a certain minimum level, biuret could be used to supply as much as 50% of the supplemental nitrogen. In the third experiment, biuret supplementation in a salt mix prior to flushing had no effect on the lambing response observed in either ewes on the range or those fed alfalfa in drylot during the flushing period. Flushing and breeding in a drylot produced significantly more lambs than supplementing ewes grazing range forage.

1202. Torell, Donald T., I. D. Hume, and William C. Weir. 1972. **Flushing of range ewes by supplementation, drylot feeding, or grazing of improved pasture.** J. Range Manage. 25(5):357-360.
Abstract: The lambing performance of range ewes was compared with that of similar ewes which were supplemented for 17 days prior to and the first 17 days of breeding (4 years), were fed in drylot (4 years), or grazed an improved pasture (2 years) over the same period. Supplementation (2.25 kg alfalfa pellets/ewe/week, fed twice weekly) did not improve lambing performance, but drylot feeding (1.82 kg alfalfa hay/ewe/day, increased the number of lambs born/ewe present at lambing from 101% to 128% ($P < 0.001$). Access to improved pasture also increased lambing percent (from 110% to 138%) ($P < 0.01$). Current feed costs, and availability and alternative uses of an area of improved pasture, will determine which of the two effective treatments is most likely to result in the greatest net returns from flushing. The observed flushing effect was associated mainly with the live-weight change over the flushing period, rather than any static live-weight effect. For every kg increase in the weight gain during flushing, lambing percentage increased by about 8%.


Guy E. Connolly

Shepherds John Hays (left) and Jim Furlong (center) work sheep with Animal Science specialist Don Torell (right), March 1975

1203. Torell, Donald T., I. D. Hume, and William C. Weir. 1974. **Factors affecting blood urea nitrogen and its use as an index of the nutritional status of sheep.** J. Anim. Sci. 39(2):435-440.
Abstract: Three experiments were conducted to study factors affecting blood urea nitrogen (BUN) and the use of BUN as an index of the nutritional status of ewes. In Experiment I, 315 ewes of varying ages grazing on mature and annual grass were flushed by supplementing daily with 0, 90, 180, 270, 360, and 450 g pelleted alfalfa hay just prior to and during the breeding season. Lambing percentage (lambs born × 100/ewe present at lambing) increased from 98% (no supplement) to 130% when 360 g pelleted alfalfa were consumed ($P < .10$). Both BUN ($P < .05$) and weight gain ($P < .05$) increased during the flushing period when alfalfa was fed. Simple correlation coefficients (r) were: supplemental N intake vs. BUN, 0.99; BUN vs. weight gain 0.95; BUN vs. lambing percent, 0.95; supplemental N intake vs. gain, 0.95; and weight gain vs. lambing percent, 0.97. In Experiment II, blood samples from 10 each of lambs, yearlings, and ewes were taken 5 times during a day to determine the effect of animal age, time of day, and variation in BUN levels among animals. Neither age nor sampling time had any significant effect on BUN level, but variation between animals within age class was significant ($P < .01$). In Experiment III, 19 to 25 ewes from each of 26 commercial flocks throughout northern California were samples for BUN prior to breeding. Since the standard deviations were rather constant irrespective of BUN level, the minimum sample size necessary for 95% of the values to be within ±10% of the sample mean varied between flocks with regression of $Y = 31.79 - .95x$ ($r = -.761$) where Y is the sample size and X is BUN value.

1204. Torell, Donald T., James G. Morris, and William C. Weir. 1974. **Effect of frequency of feeding on lamb production.** Proc. West. Sect. Am. Soc. Anim. Sci. 25:376-378.
Abstract: A 2 × 3 factorial allocation of treatments was used to investigate the effect of two levels of nutrition and three frequencies of feeding on the lambing performance and body weight changes of ewes. Two hundred eighty-eight Targhee ewes were allotted by age and condition into 6 groups which were flushed for 14 days then bred for 18 days in a feedlot. The two levels of nutrition were either 1 kg or 1.8 kg alfalfa cubes per day. The three feeding frequencies were daily, twice weekly - the week's ration divided into two feedings, or

weekly - the entire week's ration at one feeding. The ewes were classified as thin (T), medium (M), or fat (F) at the beginning of the flushing period and weighed when they entered and left the feedlot. Lambs born per ewe lambing (L/EL) for ewes given 1 kg and 1.8 kg cubes/day fed daily, twice, and once per week were 1.34, 1.54, and 1.59 for the 1 kg ewes, and 1.69, 1.72, and 1.62, respectively for the 1.8 kg ewes. L/EL for the T, M, and F ewes were 1.31, 1.56, and 1.54 for the 1 kg groups and 1.58, 1.66, and 1.82 for the 1.8 kg groups. Body weight changes of ewes fed daily, twice weekly, and weekly were -4.0, -3.3, and -1.4 kg for the 1 kg groups and 4.9, 1.6, and 2.0 for the 1.8 kg-fed groups. There were 6.2% dry ewes with 1 kg groups and 1.6% in the 1.8 kg-fed groups. It appears that feeding a week's ration once or twice per week (it takes 3 to 4 days to consume a week's ration) during breeding will result in comparable lambing percentages as feeding daily.

1205. Torell, Donald T. 1975. **Broiler litter and feedlot manure for ewe lambs (Abstract).** J. Anim. Sci. 49(1):422.
***Abstract*:** One-hundred twenty-five whiteface and Finn-Suffolk whiteface ewe lambs, stratified by breed, were allotted at weaning into three 40-lamb groups and fed: 1) 50% broiler litter plus 50% apple pulp (BL); 2) 60% feedlot manure (high concentrate ration) plus 40% almond hulls (FM) as a pellet, or 3) 60% alfalfa plus 40% almond hulls (ALF) as a pellet for 97 days prior to joining with rams and for another 49 days of breeding. Feed allocated to BL and ALF groups was adjusted to give similar N intake to the FM group, which was fed *ad libitum*. All ewes were treated as one group, on range, after breeding. Regulated feed consumption, total gain (97 days), and lambing percentage for BL, FM, and ALF were 1.82 kg, 6.2 kg, 62%; 1.88 kg, 2.2 kg, 50%; and 1.79 kg, 14.4 kg, 87%, respectively. Lambs that weighed less than 27 kg at weaning and those that weighed less than 34 kg at joining had lambing percents of 60 and 58; 17 and 33; and 90 (none less than 34 kg at joining) for BL, FM, and ALF, respectively.

1206. Torell, Donald T. 1975. **Recycling animal wastes.** Pp. 32-39 *in:* Proc. Sheep Breeding and Feeding for Profit Symp., Sheep Industry Development Program, Sioux Falls, SD, Jul. 31 - Aug 2.
Abstract: The manure of laying hens, broilers, and feedlot cattle can potentially be used as components of supplemental feed for ewes. Protein content, ash, and energy content of these animal by-products are discussed in terms of their potential for use in food supplements, as well as measures of digestibility. The author discusses pertinent Food and Drug Administration regulations pertaining to the use of such animal by-products as animal feed, as well as potential disease problems involving manure recycling. Broiler litter and caged layer manure (dehydrated) are both high in nitrogen, low in energy, are fairly well digested, and can be made safe to feed to sheep. Data from multiple studies are reviewed, with the conclusion that these by-products can be used a nitrogen sources for ruminants. The author cites a previous study with cattle, which performed well when supplemented with a feedlot manure/barley pellet. However, the author's trials at Hopland supplementing ewes with a feedlot manure/almond hull pellet showed poorer reproductive performance than ewes supplemented with broiler litter plus apple pulp, or with alfalfa plus almond hull pellets.

1207. Torell, Donald T. 1976. **Recycling animal wastes.** Pp. 20-39 *in:* Sheep and Wool Days, Special Report #457, Oregon State University, Corvallis.
Abstract: The author reprints his article of the same title (Torell 1975), but here adds reports on studies of the frequency of providing supplemental feed to ewes on rangeland at Hopland and resulting changes in lamb production (*see* Torell, Morris, and Weir 1974).

1208. Torell, Donald T., William C. Weir, and G. Eric Bradford. 1976. **Sheep research stresses management, nutrition, and breeding.** Calif. Agric. 30(7):26-31.
Abstract: The sheep research program at the Hopland Field Station has made a significant contribution to the sheep industry. The first research was designed to increase weaning weights and improve weaning percentages by protecting ewes and lambs from adverse weather. Studies were conducted to develop inexpensive range shelters, as well as economical barn-lambing systems. Range nutrition also affects weaning percentage and weights of lambs. Feeding research has provided a sound basis for supplementing ewes to increase lambing percentage, and demonstrated the economical benefits of supplementing weanling ewe lambs to moderate weight loss, improve wool production, and reduce death loss. A series of long-term breeding experiments have been conducted to identify and develop strains of sheep that are both well adapted and productive under annual grassland range conditions. These studies have evaluated the selection for rapid growth from birth to weaning as well as prolificacy or multiple births. Many of the research projects also have led to developments that will facilitate future research programs at Hopland and throughout the world.


Robert M. Timm

Shepherd John Hays with UC Davis Animal Science student interns (from left, Janet Halsebo, Susie Garrison, Nancy Post), March 1976

1209. Torell, Donald T. 1977. **Feeding sheep and goats.** Pp. 209-222 *in:* D. C. Church (ed.), Livestock Feeds and Feeding. O & B Books, Inc., Corvallis, OR.
***Abstract*:** The author provides a comprehensive review of the nutritional requirements of sheep and goats, as well as feedstuffs and feeding strategies and resulting performance. Considerable discussion is provided on feeding ewes, young lambs, and replacement ewe lambs. The section on nutrient requirements includes information on protein, energy, salt, calcium, phosphorus, selenium, other minerals, and vitamins. Water requirements for sheep are also described. A comparison of sheep nutrition on rangeland versus pastures is provided, as well as discussion of use of harvested roughages, silage, root crops, grains, by-products, and supplements. The nutritional management of ewes at flushing and breeding, on dry pasture, during gestation and lactation, and post-breeding and post-weaning is discussed. Nutritional needs and strategies for nursing lambs, including orphan lambs, are described. Creep feeding, sanitation, weaning, and fattening feeder lambs are covered. Brief information on rams is also included. Nutritional differences of goats versus sheep are briefly summarized, including feed requirements of dairy goats and hair goats.

1210. Torell, Donald T. 1979. **Sheep handling equipment.** Pp. 17-21 *in:* Western Oregon Sheep Conferences and Meetings - Summary of Reports, Oregon State Univ. Extens. Service. March 1979.
Abstract: The author reviews the behavioral principles involved in

handling and working with sheep. He provides practical suggestions and recommendations on purchase and design of equipment for handling sheep. Corrals, chutes, and working areas and their design and discussed. The advantages of the Sheep Handling Unit, a piece of equipment developed in Australia that permits large numbers of sheep to be handled with very little labor expense, are summarized.

1211. Torell, Donald T. 1979. **Increasing lamb production.** Pp. 22-30 *in:* Western Oregon Sheep Conferences and Meetings - Summary of Reports, Oregon State Univ. Extens. Service, March 1979.
Abstract: There are three major methods for increasing number of lambs born per ewe lambing. Selecting for multiple births can increase lambing percentage approximately 2% per year. Crossbreeding with a highly prolific breed such as the Finn sheep can increase number of lambs by about 25% for a ¼ breed and 40% to 50% for a ½ Finn. Flushing 10 to 14 days prior to and during breeding will increase the lambing percent. The rate of increase is influenced by the condition of the ewes at breeding, but when they are in good range condition we have increased lambing by 25% to 50% by flushing alone. For highest increase, flushing can be combined with either selection for multiple births or crossbreeding with a more prolific breed.


Tracy Borland

UC Davis veterinarian Barry Duelke and HFS principal shepherd John Hays administer treatment to lamb, Spring 1976

1212. Torell, Donald T., B. D. Duelke, and Robert H. BonDurant. 1979. **Sterilizing lambs by chemical sclerosing of epididymi (Abstract).** *In:* 71st Ann. Mtng., Amer. Soc. of Animal Sci., Univ. Arizona, Tucson, AZ, Jul. 28 - Aug. 1.
Abstract: Chemical sterilization of ram lambs was investigated as a potential alternative to surgical sterilization methods. In Phase I, 28 ram lambs were chemically sterilized with 10% formalin, and 26 were treated with 50% $CaCl_2$, injected into the tail of the epididymis at 14 to 58 days of age ($\bar{x} = 42$). Formalin-treated lambs showed no noticeable post-injection pain, whereas $CaCl_2$ caused severe discomfort. Two weeks later, 89% (25) of the formalin-treated lamb testicles were fibrotic, and 11% (3) had other palpable anomalies. Among the $CaCl_2$ group, 31% (8) were fibrotic, 65% (17) showed moderate to severe sloughing, and 3% (1) were without palpable lesions. All lambs in both treatments were castrated 55 days later and gross pathology of the testicles and epididymis showed sclerosing in all lambs. In Phase II, 44 ram lambs, age 6 months, were treated 30 days postweaning with ½ ml 10% formalin in each cauda epididymis. Eleven months later they were electro-ejaculated and 18% (8) were found to have viable sperm. Sterilizing ram lambs by chemical sclerosing of the cauda epididymi is less time consuming. There is less opportunity for infection and less stress to lambs than in surgical vasectomy. A higher degree of success with young rams was suggested by this study.

1213. Torell, Donald T. 1980. **Accelerated lambing.** Pp. D1-D13 *in:* Western Sheep Symposium, Salt Lake City, UT, Aug. 19-20.
Abstract: A real opportunity for sheep producers to improve efficiency and net return is available through accelerated lambing. Studies have shown that ewes managed and selected for production at 1 year of age will be more productive throughout their lifetime than ewes managed to lamb first at 2 years of age. Likewise, 8-month interval lambing can be an efficient, easily managed, accelerated system. With this system hormone therapy is necessary when mating is done during anestrum. The use of hormones is costly and they are not always readily available. With these factors in mind, researchers at Purdue University have studied the 8-month interval lambing without the use of hormones, using good nutrition and selection as tools. The author discusses considerations involving lambing ewes at one year of age, as well as lambing intervals of less than one year. Data on the comparative performance of various breeds are provided from other studies.

1214. Torell, Donald T. 1981. **Flushing, alternate dry feeding, and management tricks for sheep producers.** The Progressive Sheep Breeder 4(Winter):37-39.
Abstract: The article briefly summarizes current information from work at Hopland on ewe productivity, lamb survival, animal selection, increasing weaning weights, increasing multiple births, lambing birth weights, crossbreeding, nutrition, feeding intervals, and time of breeding.

1215. Van Dyne, George M. 1962. **Micro-methods for nutritive evaluation of range forages.** J. Range Manage. 15(6):303-314.
Abstract: The results of preliminary investigations on variables affecting estimates of cellulose digestibility and dry matter digestibility by artificial rumen and by nylon bag techniques are presented. Studies with both cattle and sheep under corral feeding and range grazing conditions were conducted. Forage sources included hand clipped range plants and forage samples taken from esophageal-fistulated steers and wethers grazing the same range as the rumen-fistulated animals which contained the nylon bags. Using a constant size and manner of processing and analyzing samples, but with different cellulose sources, the following variables were studied in artificial rumen investigations: time of fermentation period, method of preparing inocula, and effects of diet of the fistulated animal from which the inocula was obtained. It was found that there were increasing *in vitro* cellulose digestion values with time for all cellulose sources investigated. From 24 to 48 hours all samples of forage maintained their relative digestion values. Inocula prepared by simply straining rumen contents through several layers of cheesecloth gave as high and as uniform cellulose digestion values as did more elaborate procedures. The diet of the fistulated animal influenced the estimates of cellulose digestion. Cellulose digestion values of range forage and pure cellulose samples were considerably higher when the base diet was alfalfa hay than when it was oat hay. Using the same size and weave of nylon bag, animals, the chemical procedures, the following variables wee studied in nylon bag investigations: effect of sample weight, length of the fermentation period, variations between cattle and sheep, animal to animal variation in the same class of stock, and different procedures of rinsing the bags after removal. Sample size was inversely related to *in vivo* nylon bag cellulose digestion (for 2- to 10-g samples of found mixed annual range forage) in both cattle and sheep. Length of fermentation period appeared to have a linear and quadratic relationship to cellulose digestion in time periods evaluated (24 - 72 hrs) for both cattle and sheep. Significant differences were found between cellulose digestion of forage samples between rumen-fistulated cattle and sheep when they grazed together on the range but

not when they were fed hay. Differences in cellulose and dry matter digestion between animals of the same class of stock were variable for cattle, sheep, and type of diet. Simple rinsing of nylon bags upon removal from the animal, as compared to thorough and repeated soaking, agitation, and rinsing of the bag, resulted in highly significant but small differences in estimates of cellulose digestion but large differences (highly significant) in estimates of dry matter digestion with the light rinse values being the lower. Cellulose digestion in cattle-grazed forage was highly significantly greater than cellulose digestion in sheep-grazed forage when tested by both classes of stock, but no significant differences were found in dry matter digestibility by these techniques between these two forages. Sheep were better able than cattle to digest cellulose and dry matter in both cattle and sheep forage samples when grazed on the same range with the cattle as measured by nylon bag technique. Similar estimates of cellulose digestibility in a given feed were found in these preliminary artificial rumen and nylon bag studies. There were closer agreements between artificial rumen duplicate tubes than between duplicate nylon bags.

1216. Van Dyne, George M. 1963. **An artificial rumen system for range nutrition studies.** J. Range Manage. 16(3):146-147.
Abstract: The artificial rumen has previously been used to estimate empirically the nutritive value of range plants. Four general types of artificial rumen systems exist: 1) continuous flow, 2) semipermeable membrane, 3) all glass volumetric, and 4) all glass gravimetric. This article describes the components and operation of a system of the 4th type. It is used to evaluate the digestion of cellulose in small samples of ground forages or purified cellulose. However, digestion of other nutrients and dry matter can be followed by similar techniques. Aspects discussed include capacity, gas and pH control, and operation sequence. A schematic diagram showing the major components of the artificial rumen system is included.

1217. Van Dyne, George M., and G. P. Lofgreen. 1964. **Comparative digestion of dry annual range forage by cattle and sheep.** J. Anim. Sci. 23(3):823-832.
Abstract: Apparent digestion coefficients were calculated by ratio techniques using composition of esophageal fistula forage samples and total fecal collections from ruminal fistulated animals. All animals were grazed together and were handled similarly on an annual range where herbage decreased from 1,490 to 420 lb/acre during the summer. The internal indicators were lignin on a dry matter, silica-free, and organic matter basis, and silica on a dry matter basis. The ruminal fistulated animals were also used in conventional digestibility trials on drylot. Digestion coefficients calculated by silica ratio varied widely during the summer. There was no significant difference in digestion coefficients calculated by lignin ratio when forage and fecal composition were on dry matter, or silica-free, or organic matter basis. Sheep were equal to or lower than cattle in early summer but higher in late summer for lignin ratio digestion coefficients for dry matter, ether extract, and other carbohydrates. Sheep always digested more crude protein and less cellulose than did cattle. Digestion coefficients for sheep and cattle were closer during early than late summer for most constituents and never differed significantly for gross energy. Total fecal collection and nylon bag and artificial rumen microdigestion estimates were use to calculate forage intake and, subsequently, macrodigestion coefficients. Lignin was 4% digestible by this method; therefore, most digestion coefficients determined from microdigestion data were higher than those determined by lignin ratio. All procedures except silica ratio gave comparable seasonal trends in digestibility and differences between sheep and cattle. Variations among the esophageal fistulated animals (forage animals) caused greater variations in digestion coefficients than did variation among ruminal fistulated animals (fecal animals). Averaged over all constituents, from 10 to 13 forage or fecal animals of either class would be required to estimate digestion coefficients within 10% of the mean with 90% confidence. The average numbers of forage plus fecal animals of both classes required to estimate digestion coefficients were 29, 25, 6, 5, and 3 for crude protein, ether extract, other carbohydrates, cellulose, and dry matter, respectively. Variability in estimates of digestibility of gross energy was similar to that for digestibility of cellulose. For optimum use of a given number of animals during the summer, 1.2:1 forage to fecal animals or sheep to cattle should be used. Cattle and sheep did not differ in ability to digest pelleted alfalfa on drylot, but there were within-class differences. Four wethers and 2 steers were sufficient on drylot to estimate most digestion coefficients within 10% of the mean with 95% confidence. Averaged over all trials, about 6 wethers and 4 steers would be required to estimate cellulose digestibility. Variability on the range was 50% more than in drylot. The ruminal fistulated animals maintained their weight during 3 months grazing on dry annual range when digestible energy crude protein consumption was lower than levels calculated or reported in the literature for maintenance of animals on drylot.

1218. Van Dyne, George M., and J. H. Meyer. 1964. **A method for measurement of forage intake of grazing livestock using microdigestion techniques.** J. Range Manage. 17(4):204-208.
Abstract: Existing methods for determining forage intake are reviewed with regard to their applicability under range conditions. A new procedure for determining forage intake by grazing animals is described. This procedure involves: 1) determination of the digestion value of range forage and standard forage samples using micromethods with inocula from grazing animals, 2) prediction, by use of a regression equation, of macrodigestion from microdigestion of range forage, adjusted to microdigestion of a standard sample; and 3) use of the predicted macrodigestion estimate, composition of range forage, and composition and amount of feces to calculate forage intake. The new procedure, based on microdigestion, eliminates the necessity of assuming indigestibility of naturally occurring indicators, e.g., lignin or chromogens. The new procedure also obviates harvesting range herbages for dry-lot digestion trials, as is required in the fecal nitrogen index technique.

1219. Van Dyne, George M., and J. H. Meyer. 1964. **Forage intake by cattle and sheep on dry annual range.** J. Anim. Sci. 23(4):1108-1115.
Abstract: Lignin and silica ratio techniques and microdigestion procedures were used to estimate forage intake for cattle and sheep in one drylot feeding and three range grazing experiments. Samples of forage grazed from a dry annual range were obtained via esophageal fistulas. Ruminal fistulated animals provided estimates of amount and composition of feces and dry matter and cellulose microdigestion by nylon bag and artificial rumen techniques. Silica ratio procedures gave estimates of forage intake which were about 10% higher and were more variable than those determined by lignin ratio technique under range grazing conditions. Lignin ratio on a dry matter, a silica-free, or an organic matter basis gave similar estimates of forage intake. Forage intake by sheep, determined by lignin ratio technique, was highest in mid-summer with moderate herbage availability (1,220 lb/acre), and low in early summer with high herbage availability (1,490 lb/acre) or in late summer with low herbage availability (420 lb/acre). Forage intake by cattle varied inversely with herbage availability. For both sheep and cattle under drylot feeding, feed intakes estimated from microdigestion of cellulose *in vivo* were not significantly different from the amounts of dry matter fed. Under range grazing, forage intake estimated from microdigestion of cellulose was greater than that estimated by lignin ratio. Individual sheep varied in estimated forage intake from about 8.6 to 14.9 lb/AUE; whereas, forage intake by cattle varied from about 13.9 to 16.8 lb/AUE. Forage intake calculated from predicted macrodigestion and averaged over both cellulose microdigestion

techniques for early, middle, and late summer, respectively, was 10.3, 12.0, and 10.8 lb/AUE for sheep and 12.6, 15.2, and 17.0 lb/AUE for cattle. For the summer grazing period, the average numbers of animals required to estimate forage intake from dry annual range within 10% of the mean with 95% confidence would be 4 sheep to sample forage and 22 to sample feces, and 2 cattle to sample forage and 6 to sample feces.

1220. Van Dyne, George M., and Donald T. Torell. 1964. **Development and use of the esophageal fistula: a review.** J. Range Manage. 17(1):7-19.
Abstract: One of the foremost problems in range and pasture nutrition is making an accurate assessment of the chemical and botanical composition of the diet of grazing livestock. In recent years, the esophageal fistula has been used to obtain samples of the forage grazed by ruminants. These studies have been conducted under a wide variety of conditions in at least 6 countries on 4 continents. This article, focusing on experimental studies with domestic animals, reviews the development and use of the esophageal fistula in published literature and discusses present problems and practices. Discussion includes the historical development of the technique, surgical techniques, types of closure devices, and the forage collection apparatus. Experimental design using the technique is discussed in terms of length of sampling, chemical analyses, salivary contamination, the isotope-dilution technique, digestion of fistula samples, botanical analyses of samples, sampling frequency, and the accuracy and precision of samples. Additional discussion compares esophageal to ruminal fistula sampling and describes the behavior of fistulated animals.

1221. Van Dyne, George M., and William C. Weir. 1964. **Microdigestion of grazed annual forage, clipped herbage and standard samples by cattle and sheep.** J. Range Manage. 17(6):327-332.
Abstract: Eighteen ruminal fistulated steers and wethers each provided inocula for microdigestion studies in three range grazing trials on mature annual range and in one dry-lot feeding trial. Artificial rumen and nylon bag cellulose digestion (PCD) and nylon bag dry matter digestion (PDMD) estimates were obtained. Each animal provided microdigestion estimates on Solka-floc, on an alfalfa sample, and on forages consumed by esophageal fistulated animals grazing on the same range. Two steers and wethers each provided nylon bag microdigestion estimates on five hand-clipped range forage plants during on period on the range. Six grazed forages, an alfalfa sample, and Solka-floc were not ranked in the same order by the three microdigestion procedures. Solka-floc always had the highest digestibility, but forages varied in rank. Cellulose digestibility, but not dry matter digestibility, was higher in cattle-grazed than in sheep-grazed forage. Forages grazed by either cattle or sheep in midsummer were more digestible, by all techniques, than forages grazed in early or late summer. The mixed forage samples obtained from esophageal fistulated animals generally had higher microdigestion estimates by nylon bag technique than any of the five species hand-clipped from the range. Microdigestion estimates were correlated with macrodigestion estimates obtained by lignin ratio technique under range grazing or total collection procedures under dry-lot feeding. Over all techniques, the correlation between microdigestion and macrodigestion estimates was about 0.72. Adjusting microdigestion of range forages to that of a standard sample decreased the range of estimates but did not improve the correlation of microdigestion to macrodigestion. The correlations found were not as high as many of those in the literature for farm roughages, and reasons for possible differences are discussed.

1222. Van Dyne, George M., and William C. Weir. 1964. **Variations among cattle and sheep in digestive power measured by microdigestion techniques.** J. Anim. Sci. 23(4):1116-1123.
Abstract: Ruminal fistulated steers and wethers provided inocula for individual microdigestion estimates in three range grazing trials and one drylot feeding trial. Artificial rumen and nylon bag cellulose digestion (PCD) and nylon bag dry matter digestion (PDMD) data were obtained. Each animal provided microdigestion estimates for Solka-floc and an alfalfa sample (standards) and for forages consumed by esophageal fistulated animals grazing on the same range. Between-class and within-class of stock differences were analyzed. When averaged over all procedures, there were no significant differences in digestive power between cattle and sheep. Differences among animals within a species were less in drylot. The range of within-class differences depended upon herbage availability for cattle, type of sample for standards but not grazed forages, and technique. Animals appeared to maintain their relative ranks better for microdigestion of grazed forages than for standard samples. Averaged over all techniques and samples, there were 12 highly significant differences among 18 animals. There were more differences in digestive power among steers than among sheep. Averaged over all techniques, samples, and periods, about 6 cattle and 4 sheep would be required as inocula sources to estimated microdigestion within 10% of the mean with 95% confidence. Averaged over both species under range grazing, the required numbers varied from about 11 in early summer to 6 in late summer as compared to 3 on drylot. More sheep than cattle would be required in drylot, but more cattle than sheep would be required on the range. Average numbers required for estimating digestion of Solka-floc, alfalfa, sheep-, and cattle-grazed forages were 9, 2, 3, and 6, respectively. Fewer animals would be required for the same precision by microdigestion techniques than be macrodigestion techniques.

1223. Van Dyne, George M. 1965. **Chemical composition and digestibility of plants from annual range and from pure-stand plots.** J. Range Manage. 18(6):332-337.
Abstract: Comparisons were made of within-plant weight distribution, chemical composition by plant part, and total plant digestion by nylon bag technique of mature annual grasses and forbs collected from pure-stand plots and adjacent range. At the mature stage, plants from the plots had a greater proportion of their weight in heads and less in stems + leaves than did plants from the range. Due to source of plant, numerous differences existed in chemical composition and individual species varied widely. Averaged over all species, there was no significant difference in digestibility due to source of the plants, but there was a highly significant species by source interaction. Under the conditions of this experiment it is invalid to grow, and analyze plants from pure-stand plots in order to make inferences about their nutritive value under range conditions.

1224. Van Dyne, George M., and Harold F. Heady. 1965. **Botanical composition of sheep and cattle diets on a mature annual range.** Hilgardia 36(13):465-492.
Abstract: Botanical and chemical analyses of the diets of freely grazing range animals are essential in determining forage digestibility and nutritive values. The problem is further complicated by the fact that animals are selective in their grazing and thereby affect botanical composition of their range. Statements in the literature of forage intake and selectivity are often contradictory, or unsupported in fact, because of inadequate techniques for studying the problem. Methods based on hand sampling, observations, and stomach analyses are of questionable accuracy for evaluating quantitatively the dietary botanical composition of animals on range areas. The most recent techniques of determining diets employ esophageal and ruminal fistulas, of which the former appears to be the most effective method thus far developed for sampled diets. The objectives of this study were the utilization of esophageal-fistulated animals to 1) compare the dietary composition of cattle and sheep freely grazing together on a mature annual range; 2) to evaluate changes in dietary composition

with changes in herbage availability; and 3) to determine differences and variability in diets selected in the early morning and late afternoon, during consecutive days, and throughout the summer. Percentage botanical composition on a weight basis of cattle and sheep diets, and preference ratings for certain plants, for animals grazing on a mature annual range are presented. Composition of the dietary samples was determined by the microscopic point method on forage material collected through esophageal fistulas. The same microscopic techniques were used to determine composition of herbage clipped in the field. Dietary comparisons are made between individual animals, cattle and sheep, morning and evening grazing, grazing on consecutive days, and between lightly and heavily used range. Individual sheep differed more in diet than did cattle. Differences in most dietary components among cattle and sheep decreased as herbage became limited.

1225. Van Dyne, George M., and Harold F. Heady. 1965. **Dietary chemical composition of cattle and sheep grazing in common on a dry annual range.** J. Range Manage. 18(2):78-85.
Abstract: Cattle and sheep equipped with esophageal fistulas were used to secure samples of dietary forage from a dry annual range in early morning and late afternoon on 5 consecutive days early in July, August, and September. Dietary chemical composition was compared on dry matter, silica-free, and organic matter bases. Herbage availability varied from about 1,490 to 420 lbs/acre from early to late summer. Diets had more crude protein and gross energy but less silica and total ash in early than in late summer. Lignin content of the diet did not change significantly during the summer. Some dietary constituents were higher in middle than in early or late summer. There were differences in diets among days within a sampling period for silica and cellulose. Averaged over both cattle and sheep for the entire summer, there was no significant difference between chemical constituents in morning and afternoon diets. However, afternoon cattle diets were higher in crude protein than morning diets. Crude protein, other carbohydrates, and silica-free ash were higher in sheep than in cattle diets. Silica and cellulose were higher in cattle than in sheep diets. Cattle and sheep did not respond the same way to decreased availability of herbage, so significant period by class of stock interactions occurred for several constituents. Differences in dietary chemical composition among animals of either class could not be shown if composition was calculated on a dry matter basis, but important differences existed when dietary composition was expressed on a silica-free or organic matter basis. When comparing main effects and their interactions, i.e., periods, days, times of day, and classes of stock, the basis of calculation was not as important as with individual animals. Except for ether extract, 6 or fewer animals would be sufficient to sample all dietary chemical constituents within 10% of the mean with 95% confidence. Four or fewer animals would be adequate for sampling in most period by class of stock combinations.

1226. Van Dyne, George M., and Harold F. Heady. 1965. **Interrelations of botanical and chemical dietary components of animals grazing dry annual range.** J. Anim. Sci. 24(2):305-312.
Abstract: Simple linear correlations were calculated among dietary chemical and botanical constituents for cattle and sheep grazing in common in the summer on a dry foothill annual range. The mature annual herbage varied from 1,490 to 420 lbs/acre in three experimental periods. Dietary components investigated were 24 species, parts, or groups of plants and 8 modified proximate chemical constituents. Correlations for chemical composition on dry matter, silica-free, and organic matter bases were similar. Correlations among botanical dietary component pairs were significant in all 6 period by class of stock data groups in 17 comparisons, but were not significant in 44 comparisons. Cattle grazed a more constant ratio than did sheep of *Bromus* to all grasses, of *Trifolium* spp. to all legumes, of forb heads to total forbs, and of shrubs to perennials. The following ratios were inversely proportional to herbage availability in cattle and sheep diets: total forbs to unidentifiable forbs, grass stems to forb stems, and total forbs to forb stems. Directly proportional to herbage availability were forb heads to total heads. None of the dietary chemical constituent pairs was significantly correlated in all 6 data groups. This illustrates changing dietary selectivity with less herbage availability. In late summer, cattle and sheep had similar correlations for many dietary chemical constituents because less herbage was available for selection. Sheep had more and usually higher correlations than did cattle of dietary botanical and chemical components during the summer. Important direct correlations of botanical to chemical components were total heads and grass heads with other carbohydrates, and shrubs with lignin. Inverse correlations were found for total grasses and grass stems with ether extract, total leaves and forb leaves with other carbohydrates, and *Bromus* spp. with crude protein. Some botanical and chemical components were significantly correlated directly in some instances but inversely in others. Examples were total grasses and perennials with cellulose, *Trifolium* species with total ash, and *Erodium botrys* with silica.

1227. Van Dyne, George M., and William C. Weir. 1966. **Comparison of microdigestion techniques under range and drylot conditions.** J. Agric. Sci. 67:381-387.
Abstract: Digestion of cellulose (PCD) and dry matter (PDMD) in nylon bags suspended in the rumen, and the digestibility of cellulose in the artificial rumen were compared during three experimental periods on the range and one period on drylot. Nine each of ruminal fistulated wethers and steers provided inocula for artificial rumen (*in vitro*) studies and carried the nylon bag (*in vivo*). The same animals were used in all 4 experimental periods. Solka-floc and a sample of alfalfa were used as standards in all trials. Forage samples were collected from esophageal fistulated animals which grazed the same range as the ruminal fistulated animals. These mixed forage samples were also digested by *in vitro* and *in vivo* techniques. Solka-floc was of limited value as a standard sample for the *in vivo* trials because seeds apparently ruptured the nylon bags enough to allow passage of the finely divided Solka-floc through the wall of the bags. The results also imply that non-cellulosic material may have entered the bags and adsorbed on the Solka-floc. Considering all samples, there was no significant difference between PCD and PDMD *in vivo*, and PCD *in vitro* was slightly but significantly lower. The *in vivo* digestion results appear to reflect changes in quality of the base diet more than do the *in vitro* results. Regression equations and correlations between microdigestion estimates by the different techniques were significant if samples with a wide range of digestibilities were included in the analysis. Within ranges of digestibilities of 10% or less, the equations were not useful for predictive purposes. Range forage samples taken from esophageal fistulated cattle or sheep were digested better when the base feed was pelleted alfalfa than when it was range forage. Digestion of an alfalfa sample was less affected by the base diet. Solka-floc was digested better *in vitro* when the inocula came from animals grazing on the range than from animals fed pelleted alfalfa. Sample sizes from 1.85 to 2.15 g and cellulose contents of from 27% to 97% did not produce significant regressions of percentage cellulose digestion on cellulose or sample weight.

1228. Weir, William C., and Donald T. Torell. 1953. **Salt-cottonseed meal mixture as a supplement for breeding ewes on the range.** J. Anim. Sci. 12(2):353-358.
Abstract: A mixture of 25% salt and 75% cottonseed meal self-fed was compared with hand-fed cottonseed meal as a supplement feed for pregnant and lactating ewes under range conditions. The supplement was fed from October 1 to March 2 to 48 range ewes. The average daily intake per ewe ranged from 0.073 lb cottonseed meal and 0.024 lb salt to 0.347 lb cottonseed meal and 0.116 lb salt.

Lamb production, wool production, and ewe weights gave no indication of adverse effects due to the large salt intake.

1229. Weir, William C., J. H. Meyer, and G. P. Lofgreen. 1959. **Symposium on forage evaluation: VI. The use of the esophageal fistula, lignin, and chromogen techniques for studying selective grazing and digestibility of range and pasture by sheep and cattle.** Agron. J. 51:235-237.
Abstract: Selective grazing, or the difference between what is available to the animal and what the animal actually consumes, is a major obstacle to effective studies of the nutritive value of pasture herbage. To investigate this difference, sheep were fitted with esophageal fistulas and the forage they consumed was compared with hand-clipped forage from the same grazing area. The crude protein was consistently higher and the crude fiber content consistently lower in the forage collected by the sheep. Lignin and ether extract showed no consistent pattern. Silica-free ash content of the selected material tended to be higher. Botanical composition of the grazed forage compared to the hand-clipped forage was also studied. A seasonal pattern of preference was indicated. Sheep tended to avoid bur clover (*Medicago hispida*) early in the growing season but selected for it later. Filaree (*Erodium* spp.) appeared to be selected early, avoided in May, and selected during the summer. Grass was selected early in the season and definitely avoided in the summer. Similar studies with cattle suggest very similar results with regard to animal grazing selectivity. These experiments indicate that research to evaluate the nutritive value of forages must be based on methods which represent the forage consumed rather than that available.

1230. Weir, William C., and Donald T. Torell. 1959. **Selective grazing by sheep as shown by a comparison of the chemical composition of range and pasture forage obtained by hand clipping and that collected by esophageal-fistulated sheep.** J. Anim. Sci. 18(2):641-649.
Abstract: Selective grazing by sheep was studied by comparing the chemical composition of forage samples obtained by hand-clipping and by esophageal-fistulated sheep on a wide variety of range and pasture conditions at various seasons of the year. The sheep consistently selected forage higher in protein and lower in crude fiber than that obtained by hand-clipping. No consistent differences in lignin or ether extract content were obtained. The silica-free ash content of the forage collected by the fistulated sheep tended to be higher than that of the hand-clipped forage. At least part of this difference must be attributed to the ash content of the saliva. Pooling all data for ungrazed forage indicated that fistulated sheep selected forage containing 4.1% (±0.55) more protein and 3.5% (±0.29) less crude fiber than found in hand-clipped forage. When the forage had previously been grazed by a large flock of sheep, the differences were somewhat smaller– 3.0% (±1.1) for protein and 0.90% (±0.44) for crude fiber. The difference for crude fiber between grazed and ungrazed forage was highly significant. Correlation and regression studies indicated it was not feasible to estimate what a sheep would eat from hand-clipped material.

1231. Weir, William C., Roderick A. Shippey, Fremont L. Bell, L. V. Maxwell, and Donald T. Torell. 1961. **Cobalt bullets.** Calif. Agric. 5(12):15.
Abstract: The element cobalt is essential in the feed of sheep in minute amounts. Whether or not it needs to be provided as a special supplement depends on the amount present in natural feed. The small amount required by sheep is difficult to assay. Feed or forage containing more than 0.07 parts per million of cobalt in feed (on a dry matter basis) has been shown to prevent deficiency. A cobalt bullet consisting of cobalt salt and a special clay has been developed in Australia to provide a continuous, very low concentration source of cobalt for sheep. The bullet is deposited in the esophagus of the sheep, which swallows it, and the bullet remains in the reticulum to slowly dissolve. Tests to determine if this supplementary cobalt would result in additional weight gain by lambs were conducted at Hopland and elsewhere. None of the tests indicated that the cobalt treatment appreciably improved gain by lambs. In some of the trials, the change in weight was higher in the treated compared to control animals, but the differences were not significant. The bullets have been reported to glaze over on the surface under some conditions and become ineffective. This condition has been prevented by administering a steel pellet such as an engineer's ½ × ½-inch grub screw along with the bullet. This provides constant abrasion and prevents the bullet from developing a coating. Tests are continuing at Hopland to determine if this condition might have affected the trial results. As the coating takes some time to limit the availability of cobalt from the bullet, it is considered unlikely that this phenomenon appreciably influenced the results reported here.


Jim Mullins, SR Press Democrat

(Left to right) UC Davis animal scientists Bill Weir and Eric Bradford, Mendocino Co. farm advisor Rod Shippey, at Sheep Field Day, March 1965

1232. Weir, William C. 1962. **Intake by sheep of pelleted feeds of varying composition.** Proc. West. Sect. Am. Soc. Anim. Prod. 13:XIV-1 - XIV-6.
Abstract: This trial investigated the influence of the composition of feed pellets upon the selectivity and intake of sheep. Five types of pellets were prepared by the same processing. The chemical composition varied widely. When mature wethers were offered a choice of all five types, they demonstrated their ability to differentiate between pellets even though fed in differing feedboxes each day. Pellets consisting of 70% alfalfa and 30% barley or those containing only alfalfa were consistently selected in preference to other types. When these were removed, Sudan pellets were preferred to straw or brush pellets. When forced to choose between straw or brush, straw was unanimously selected. Intake expressed as grams air-dry-feed per $kg^{.75}$ body weight was analyzed statistically. Intake was affected by the type of pellets available, with a reduction when only straw and brush were offered, and markedly reduced when only brush was fed. Significant variation in intake occurred between sheep. Intake was significantly reduced on the first day of each period following a change in the feed available.

1233. Weir, William C., and Donald T. Torell. 1967. **Supplemental feeding of sheep grazing on dry range.** Agric. Exper. Sta. Bull. 832, Div. Agric. Sci., Univ. Calif. 48 pp.
Abstract: Seasonal changes in chemical composition of range forages and their effect on the nutrition of grazing animals have been investigated by many workers. Animals grazing on predominantly grass-range forage are likely to have nutrient deficiencies during the

dry-feed season. Producers of weanling ewe lambs are interested in keeping them thrifty, growing, and producing a good clip of wool, but sometimes this presents problems. Development of the esophageal-fistula technique for obtaining samples of what livestock eat has helped with these problems by increasing our knowledge of feed consumed on the range, and thus suggesting nutrient supplements for optimum production. This bulletin is a summary of 7 years of investigation to determine the amount and kind of feeds, as well as the frequency of feeding, for proper supplementation of weanling lambs grazing on dry annual-range forage. Weanling ewe lambs grazing on low-protein, dry annual range responded to a wide variety of supplemental feeds. Most effective as supplements were high-protein meals– cottonseed meal and soybean meal. Alfalfa pellets made from high-quality dehydrated forage were also effective in preventing weight losses and increasing wool production. A mixture of half cottonseed meal and half barley was less effective than cottonseed meal alone. Barley and molasses-dried beet pulp were the least effective supplements used. The addition of urea and diammonium phosphate to molasses-dried beet pulp introduced palatability problems which need further clarification. One-quarter pound per sheep per day of alfalfa, cottonseed meal, or soybean meal appears to be the practical minimum level at which to supplement. Through compensatory growth, unsupplemented lambs tended to overcome their handicap and become as large at maturity as those which were supplemented during their weanling year. There was no lifetime effect on either lamb or wool production following the year of supplementation. Response to supplementation of both body-weight gain and increased wool production was related to the nitrogen provided by the supplement. The intake of supplement can be successfully limited by the addition to salt to the supplement. Another labor-saving practice is the feeding of the supplement once, rather than 5 or 7 times, per week. Carcass composition studies show that body- plus wool-weight changes tend to underestimate the changes in energy storage and loss taking place in yearling sheep. Data indicate that the increased wool clip resulting from supplementation will pay approximately half of the feed cost of the supplement used in these trials.

1234. Weir, William C. 1969. **Basis for use of simplified techniques to evaluate alfalfa for hay and brush for browse in California.** Pp. R-1 - R-6 *in:* Proc., 1st National Conference on Forage Quality, Evaluation and Utilization, Univ. Nebraska, Lincoln, NE, Sept. 3-4.
Abstract: A test of nutritive value to be applicable to routine evaluation of forages ideally should have the following characteristics: 1) provide a reasonably accurate prediction of nutritive value, 2) require a small (1 kg or less) sample of the forage under test, and 3) be simple enough to permit rapid evaluation with a minimum of equipment in commercial laboratories. A modified crude fiber analysis has been developed which has simplified the ether extraction step and eliminated the ashing for mineral matter. By including the ash (mainly silica) with the crude fiber an improved estimate of nutritive value was obtained for alfalfa. Tables were prepared that indicated the digestible protein and total digestible nutrients in alfalfa hay as estimated from the modified crude fiber content and dry matter content. To further facilitate comparisons of alfalfa to standard feeds on a monetary basis, alfalfa of varying modified crude fiber and dry matter content was compared to barley and cottonseed meal. The test has met with widespread acceptance with a considerable portion of California hay being sold on the basis of the modified crude fiber analysis. Establishing the nutritive value of feeds consumed by livestock on California's rangelands consisting of grasses, forbs, and shrubs remains a challenging problem. Early results from tests conducted at the Hopland Field Station with sheep fitted with esophageal fistulas have been promising. Other work done at Hopland when the nutritive value of range feeds has been evaluated with monometric gas and VFA production by rumen microbes has also yielded promising results.

1235. Wilson, A. D. 1969. **A review of browse in the nutrition of grazing animals.** J. Range Manage. 22(1):23-28.
Abstract: This review article discusses the presently available literature on the chemical analyses, animal preference, digestibility, and intake of browse and on the production of animals grazing on browse. Browse is defined here as the leaves of shrubs and trees growing in areas of low or intermittent rainfall. Browse is said to provide supplements of protein and energy when grasses are mature and of low value and a reserve of feed that can be utilized in times of drought. Most of the literature supporting these views comes from the chemical analyses of browse and grasses, and from pen feeding trials. There is surprisingly little support in the form of production response by grazing animals, including both livestock, and most game animals that utilize browse. Since browse is used as a grazed plant, the most important information regarding its value will come from grazing studies and from grazing studies that use the system of grazing appropriate to the region. Ideally these studies would involve paired grazing areas, one with browse and one without. Then the breakdown of browse-grass comparisons would be better studied.

1236. Wilson, A. D., William C. Weir, and Donald T. Torell. 1971. **Evaluation of chamise (*Adenostoma fasciculatum*) and interior live oak (*Quercus wislizenii*) as feed for sheep.** J. Anim. Sci. 32(5):1042-1045.
Abstract: Measurements were taken of feed intake, composition, and digestibility of the diet of sheep grazing areas of chamise, live oak, unimproved grassland, and improved (clover) grassland. Collection of diet samples by esophageal fistula showed that brush was only eaten in significant amounts when all alternative herbaceous material was removed. Crude protein content of the diet on brush area (7% to 9%) was similar to that in the unimproved grassland (8% to 10%) but much less on the improved grassland containing clover (15%). In summer when brush became a major constituent of the diet, the sheep on grasslands ate a diet high in *in vitro* digestibility (65% compared with 45%) and had higher food intakes (980 to 1030 g digestible organic matter/day compared with 240 to 270 g/day) than the sheep on the brush areas. The brush species appear to be of limited feed value for sheep.

1237. Wilson, A. D., William C. Weir, and Donald T. Torell. 1971. **Comparison of methods of estimating the digestibility of range forage and browse.** J. Anim. Sci. 32(5):1046-1050.
Abstract: The apparent digestibility of grass, grass-clover, chamise (*Adenostoma fasciculatum*) and interior live oak (*Quercus wislizenii*) range, as grazed by sheep on three occasions, was determined by lignin ratio, two-stage *in vitro* digestion, *in vitro* digestion of cell walls, summative equation, and fecal nitrogen. For the grass and grass-clover range, dry matter digestibilities were 60% or higher and general agreement was obtained between methods. For the browse forages, dry matter digestibilities were within the range 40% to 60% or higher and there was less agreement between methods. Lignin ratio gave consistently low and fecal nitrogen consistent high estimates of digestibility. The two-stage *in vitro* procedure gave slightly lower estimates than the cell wall *in vitro* procedure and the summative equation. The use of standard or permanganate methods of lignin analysis gave less reliable estimates of digestibility than did the acid-detergent method.

Jan Washburn

2001. Anderson, John R., W. Olkowski, and J. B. Hoy. 1967. **Relationship between host attack rates and CO_2-baited malaise trap catches of certain *Symphoromyia* species (Abstract).** P. 77 *in:* Proc. Calif. Mosq. Control Assoc., Vol. 35, San Francisco, CA, Feb. 5-8.
Abstract: Five Malaise traps within a cross-shaped grid and another trap, located one-half mile away and near a group of penned, semi-tame deer, were operated in Mendocino County for 20 consecutive days beginning May 27, 1966. On 13 of these days host-seeking females were seen feeding on deer by an observer recording the number of flies feeding on several deer at 10-minute intervals from 0800 to 1700 P.S.T. During the same hours on these 13 days the 6 traps captured 3,570 *Symphoromyia sackeni* and 2,353 members of the *S. pachyceras* complex. CO_2 emission rates (about 2,000 ml/min) were determined by the end of the day weight losses of styrofoam ice chests stocked with 15 lbs dry ice per day. There was no significant difference in CO_2 emission levels between trap sites on given days, but there was great variation in the number of flies captured at different sites. The correlation between trap catches in the grid and the numbers of *S. sackeni* observed as hosts was 0.68 ($0.05 > P > 0.01$); that for the *S. pachyceras* complex was 0.88 ($0.001 > P$). Correlations between fly catches in the lone trap near penned deer and the number of females observed on deer were 0.73 ($0.01 > P > 0.001$) for *S. sackeni* and 0.83 ($0.001 > P$) for the *S. pachyceras* complex. These high correlations and the almost identical correspondence between daily fluctuations in the total number of flies feeding on hosts and those caught in traps indicate that trap catches are as sensitive to changes in the day-to-day feeding populations as are observations on hosts. The above correlations also indicate that the traps were catching the same physiologically-defined portion of the population as were being attracted to hosts. These results show that it is possible to eliminate the many man hours necessarily involved in direct host observations and yet permit one, by use of CO_2-baited Malaise traps, to obtain comparable data on factors influencing attack rates, feeding cycles, parity rates, etc. as could be obtained by constant observation and collection of flies from hosts.

2002. Anderson, John R., and W. Olkowski. 1968. **Carbon dioxide as an attractant for host-seeking *Cephenemyia* females (Diptera: Oestridae).** Nature 220(5163):190-191.
Abstract: Female bot flies (*Cephenemyia apicata* and *C. jellisoni*) were captured in traps baited with CO_2. The most productive trap sites were in wooded areas near clearings. All females examined contained fully developed 1st-instar larvae in their uterus. No bot flies were found near taxidermically mounted deer heads. CO_2 probably plays an important part in directing the search of host-seeking *Cephenemyia* females.

2003. Anderson, John R., and J. B. Hoy. 1972. **Relationship between host attack rates and CO_2-baited insect flight trap catches of certain *Symphoromyia* species.** J. Med. Entomol. 9(5):373-393.
Abstract: Correlation coefficients of 0.612 and 0.884, respectively, for the numbers of females of *Symphoromyia sackeni* and members of the *S. pachyceras* complex attacking deer versus those caught in traps emitting ca 2.4 liters CO_2/min established that trap catches excellently reflected the day-to-day activity of the host-seeking portion of the fly populations as measured by their proportional activity at unrestrained hosts. The adjusted numbers of females attacking hosts per day were nearly identical to the numbers of females caught in traps per day. As traps also proportionately caught females in the same gametogenic states as those collected from deer, we conclude that the traps functioned as substitutes for deer for these host specific flies, particularly with respect to the numbers of the *S. pachyceras* complex caught each day versus the numbers attacking deer. This is the first report of a trap which quantitatively functions as a substitute for the natural host with respect to the daily attack rate of a hematophagous arthropod. There were highly significant differences among sites with regard to trap catches of both *S. sackeni* and members of the *S. pachyceras* complex. Catches of the latter were proportional to the percentage canopy cover surrounding trap sites, whereas wind direction had the greatest effect on the numbers of *S. sackeni* caught at each site. The relationships between canopy cover, trap locations and catches, and wind directions showed that both *S. sackeni* and members of the *S. pachyceras* complex responded to the traps by orienting in an upwind direction and that the flies were being attracted from distances of up to 50 to 60 m. Comparison of the ratios of *S. sackeni* to the *S. pachyceras* complex at deer to their ratios in traps showed that the former species remained near its peak population density whereas the population of the latter declined rapidly during the study. Other data indicated that the traps were less attractive for *S. sackeni* than for members of the *S. pachyceras* complex. Although *S. sackeni* was considerably more abundant during the study than the members for the *S. pachyceras* complex, and the species which we nearly always caught in fewer numbers than expected in the traps, it was the species whose segments of the populations were strikingly trapped out from about a 5-ha area by a concentration of 5 traps. This seeming paradox is clarified by postulated differences in the behavior of *S. sackeni* and members of the *S. pachyceras* complex. In addition to *Symphoromyia* species, CO_2-baited traps caught large numbers of many obligate and facultative mammalophilic bloodfeeding species. None or only few of any species were caught in unbaited traps.

2004. Anderson, John R., and Clarence J. Weinmann. 1972. **The population dynamics, parity profiles and infection rates of the tabanid vectors of *Elaeophora schneideri* (Filariidae) in California.** P. 290 *in:* Abstracts, 14th Int. Congr. Entomol., Canberra, Australia. Aug. 22-30.
Abstract: Research revealed that both *Hybomitra procyon* and *Tabanus monoensis* served as vectors of *E. schneideri* (Filariidae) to black-tailed deer, *Odocoileus hemionus columbianus*. Incidence of infection increased with host age with nearly 50% of deer over 3 years old being infected. The worm was very rare in animals less than 1 year old. CO_2 trap studies over a 3-year period revealed that *H. procyon* served as an early spring vector (before fawns are born) and, that after a vector-free period of about 2 months, *T. monoensis* served as a summer-fall vector. Infection rates of parous females revealed that nearly 30% of the *H. procyon* and about 20% of the *T. monoensis* had infective or developing stage larvae in *E. schneideri*. The maximum number of gonotrophic cycles completed was 3, and in early spring infective filariae occurred only in 2-parous females.

2005. Anderson, John R., W. Olkowski, and J. B. Hoy. 1974. **The response of tabanid species to CO_2-baited insect flight traps in northern California (Diptera: Tabanidae).** Pan-Pac. Entomol. 50(3):255-268.
Abstract: A total of 18 species of tabanid females was caught in CO_2-baited traps between 6 April and 26 June 1966. The baited traps caught about 10 times as many female tabanids as were observed at deer, and there were fewer significant differences among trap site catches for the most abundant tabanid species than for species of *Symphoromyia* previously studied. Wind direction and the percentage canopy cover surrounding traps had little effect on tabanid catches at various trap sites. The ratio of tabanids caught in dry ice-baited versus unbaited traps was 57:1. Daily host-seeking activity of various tabanid species occurred within well-defined temperature ranges; for all species activity was suppressed below 23.9 and above

32.2°C. Normal host-seeking times for most species were markedly altered on hot days (daily maximum temperature above 32.2°C). Eleven of the 18 species trapped fed on deer at temperatures between 21.1 and 37.8°C; species of *Chrysops* fed on the face and ears, *Silvius* most commonly on the rear legs, *Hybomitra* on the face, and *Tabanus* on the neck, back and rarely the face. The ratio of *Symphoromyia*:tabanid species feeding on deer was about 40:1.

Adult female deer nose bot fly, *Cephenemyia* sp.

2006. Anderson, John R. 1975. **The behavior of nose bot flies (*Cephenemyia apicata* and *C. jellisoni*) when attacking black-tailed deer (*Odocoileus hemionus columbianus*) and the resulting reactions of the deer.** Can. J. Zool. 53(7):977-992.
Abstract: Larviposition behavior by *Cephenemyia jellisoni* involved a covert, inaudible hovering-"stalking" flight with attacking females usually remaining undetected until the moment of larviposition. In contrast, *C. apicata* landed on or near deer and became objects of attraction eliciting the curiosity of deer and causing them to orient to the fly in a position vulnerable to larviposition. The final phase of attack by *C. jellisoni* was initiated from a blind spot in front of, and below, the deer's nose, whereas visible *C. apicata* attacked from perched positions. After flies squirted larvae into deer's nostrils, deer jerked back their heads and sneezed as they simultaneously shook their heads and lowered their noses to the ground. A series of other post-larviposition behavioral responses of deer are described, as is their characteristic fly alert position and behavior. Encounters with *C. apicata* and *C. jellisoni* females that larviposited in their nostrils led to the recognition of these flies by educated deer and to their responding with anti-nose-bot-fly behavior resulting in their evading females attempting to larviposit. Deer did not respond to flies presented for them to smell, but when tethered *C. jellisoni* hovered in view of experienced deer, deer exhibited the characteristic evasive reactions provoked when wild flies were spotted. Deer also responded similarly when *Cephenemyia* larvae were "finger inoculated" into their nostrils.

2007. Anderson, John R., Richard Garcia, and G. A. H. McClelland. 1980. **Mosquitoes from trees.** Calif. Agric. 34(3):14-15.
Abstract: The western treehole mosquito, *Aedes sierrensis*, breeds naturally in water-holding holes, crotches, and stumps associated with many kinds of trees. Control of this mosquito is often difficult because it is time-consuming and difficult to find all naturally camouflaged breeding sites, especially those 10-20 feet above ground. Because of its unique dependence upon trees, this mosquito is one of the common parkland and home yard pests of people and pets.

2008. Anderson, John R., and S. Shikuma. 1980. **Fumigant toxicity to eggs of *Aedes sierrensis* (Abstract).** P. 80 *in:* Proc. Calif. Mosq. Vector Control Assoc., Anaheim, CA, Jan. 20-23.
Abstract: When eggs of the western treehole mosquito (*Aedes sierrensis*) from laboratory colonies were exposed to fumigants in laboratory containers of 1735 or 26,000 cm^3 fitted with loose lids, the percentage mortality of eggs was related to time of exposure and size of container. Mortalities of 53-100% resulted from 1- to 4-hour exposures to 1/6 of a Shell No-Pest Strip (20% Vapona), whereas 8-cm strips of Hartz Dog Flea Collars (13.7% active ingredient) resulted in mortalities of only 4-6%. In field studies, most treeholes treated with NPS and sealed with plastic for 24 to 67 hours showed a 95-99% mortality of exposed eggs after 48 to 67 hours. When water in the naturally-filled treeholes was siphoned in January 1980, results showed no larvae in one hole, one dry hole, most holes with 10 to 25 larvae/250 ml, and one hole each with 100 and 150 larvae/250 ml. Most of the 10 untreated holes also had 100 to 150 larvae/250 ml of water. These results suggest that a longer exposure or more powerful fumigant would kill all residual eggs in temporarily dry tree holes.

2009. Anderson, John R. 1986. **Obligate development of *Cephenemyia apicata* (Oestridae) in bronchi of host (Abstract).** P. 8 *in:* Abstracts, 1st Int. Congr. Dipterology, Budapest, Hungary.
Abstract: Species of *Cephenemyia* (Diptera: Oestridae) are believed to develop exclusively in the nasal cavities and pharnyx of cervids, although larvae of various sizes occasionally have been reported from the trachea, lungs, or bronchi of deer. In contrast to this general view, studies of *C. apicata* and *C. jellisoni* in the Columbian black-tailed deer in northern California have revealed that, after larviposition, the 1st-instar larvae of *C. apicata* move to the lungs as an obligate phase of the life cycle. First instars remain and grow in the bronchi for 5-6 months. After more than doubling in size, the large 1st instars migrate to the nasopharyngeal area where ecdysis to the 2nd instar occurs. As with other species of *Cephenemyia*, development of the 2nd- and 3rd-instar larvae of *C. apicata* occurs in the retropharyngeal pouches. *C. apicata* is thought to be the first species of Oestridae with a recognized obligate phase of its life cycle occurring in the lungs of its host. Seasonal activity of adults and presence of larvae revealed that *C. apicata* has one generation per year and that *C. jellisoni* has two. Larvae of both species co-occur in the host year-round but, like other *Cephenemyia* species, 1st instars of *C. jellisoni* develop in the head. Areas routinely examined for *Cephenemyia* larvae of both species included the respiratory system from the nostrils to the larger bronchi. Ligatures prevented larvae from crawling from the lungs to the nasopharynx.

2010. Anderson, John R., David E. Egerter, and Jan O. Washburn. 1986. **The biology and biological control potential of *Lambornella clarki* (Ciliophora: Tetrahymenidae), an endoparasite of the western treehole mosquito, *Aedes sierrensis*.** Pp. 149-150 *in:* Proc. Ann. Conf. Calif. Mosq. Vector Control Assoc., Redding, CA, Mar. 16-19.
Abstract: Previous observations of ciliatosis in mosquitoes are reviewed, and current studies of the ciliate *Lambornella clarki*, an endoparasite of the treehole mosquito *Aedes sierrensis*, are described. The life cycle of this ciliate is summarized. At our principal study site in Mendocino County (Hopland), approximately 50% of treeholes are positive for *L. clarki*. This widespread distribution indicates that dispersal by infected adult mosquitoes is indeed effective. In addition, we have found persistence within treeholes to be excellent with 90% of treeholes sampled over 3 years remaining positive for *L. clarki*. The occurrence of *L. clarki* in treeholes throughout California is noted. Recent studies indicate that *L. clarki* is a major cause of mortality in developing larval populations of *Ae. sierrensis.* This parasite, therefore, appears to have much promise as a manipulated biological control agent of *Ae. sierrensis* and possibly other container-breeding mosquito species.

2011. Anderson, John R., Jan O. Washburn, and M. E. Gross. 1986.

Mass production, storage, and field release of *Lambornella clarki*, a pathogen of *Aedes sierrensis*. Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 21-22.
Abstract: Ongoing field studies suggest that the endoparasitic ciliate *Lambornella clarki* is the most common pathogen to reduce mosquito survivorship in nature. It has many traits desirable in a potential biological control agent, including an active host-seeking stage, a desiccation-resistant cyst, high infection levels in nature, and self-dispersal via infected adults. In laboratory cultures, we have been able to maintain populations of *L. clarki* that have continued to multiply in the absence of larval mosquito hosts for 5 months. Further, after 6 and 20 weeks, *L. clarki* was found to be infective to first stage *Aedes sierrensis* instar larvae at 11°C. These results indicate that the pathogen can be maintained and increased in the absence of its natural host without a loss of pathogenicity.

2012. Anderson, John R., Jan O. Washburn, and David E. Egerter. 1986. **Life cycle of the pathogen *Lambornella clarki* and its impact on *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 20-21.
Abstract: Ciliate species that parasitize mosquito larvae have been identified in Europe, Asia, Africa and North America. The ciliate *Lambornella clarki* has the western treehole mosquito, *Aedes sierrensis*, as its natural host. The biology and impact of *L. clarki* on *Ae. sierrensis* has been studied by collecting and monitoring larval and adult mosquito populations at Hopland and at other sites in California over 3 years. The biologies of these two species are synchronized to the Mediterranean climate of western North America; both have desiccation-resistant stages that help them survive the 3-5-month dry season when treeholes are dry. In laboratory trials, we determined that all 4 larval instars of *Ae. sierrensis* are attacked by free-swimming ciliates, but that ciliates do not form invasive cysts on pupae. Larvae infected as first or second instars usually die during later stages. Some larvae infected as third instars, and most infected as fourth instars, eclose successfully into infected adults. Infected adults transfer the pathogen among treeholes. Field data on infection levels in natural populations indicate that *L. clarki* is the most important extrinsic mortality factor in treeholes harboring the pathogen. At Hopland, ciliatosis eliminates 50% or more of the larval population in many treeholes.

2013. Anderson, John R., Jan O. Washburn, and M. E. Gross. 1987. **Mass production, storage, and field release of *Lambornella clarki* (Ciliophora: Tetrahymenidae), a pathogen of *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 22-23.
Abstract: *Lambornella clarki* is a widely distributed parasite of the western treehole mosquito *Aedes sierrensis* in California. This ciliate attacks mosquito larvae by forming invasive cysts on the host cuticle. Ciliates penetrate the cuticle and enter the host's hemocoel where they multiply; ultimately, these endoparasitic ciliates kill their host, transform into free-living trophonts, and escape via ruptures in the cuticle. Within 48 hours of release, a portion of the ciliate population transforms into astomatous, spherical cells (theronts) which form new invasive cysts on surviving hosts. We wished to improve *in vitro* methods of culturing *L. clarki* and to evaluate production and storage of the desiccation-resistant cysts. We also wished to determine the success of previous parasite releases. These objectives support the further development of this parasite into a potentially successful biological control agent. By modification of our *in vitro* culture method, we have achieved a 3-fold increase in parasite yield, now routinely producing ciliate densities in excess of 500 cells/ml weekly in 100-ml batch cultures. We have found an efficient means of transforming free-living trophonts into parasitic theronts. To date, we have had only limited success in producing desiccation-resistant cysts. We have maintained populations of *L. clarki* trophonts *in vitro* continuously for 20 months without a loss of pathogenicity. Field observations indicate that in the absence of mosquitoes this facultative parasite can persist indefinitely feeding on microorganisms. In laboratory studies, we discovered that *Ae. sierrensis* larvae produce a waterborne factor that causes rapid morphogenesis of free-living trophonts into parasitic theronts. In spring 1987, 13 months after parasite release, 27% of treeholes in San Diego County and 46% in Orange County contained mosquito larvae infected with *L. clarki*. In fall 1987, 20% and 36% of treeholes in San Diego and Orange Counties, respectively, contained parasites. In all holes successfully inoculated in 1986, the parasite persisted for the 2 subsequent wet seasons.

2014. Anderson, John R., and Jan O. Washburn. 1988. **Mass production, field release, and persistence of *Lambornella clarki*, a parasite of *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 26-28.
Abstract: *Lambornella clarki* (Ciliophora: Tetrahymenidae) is a facultative endoparasitic protozoan that lives in water-filled treeholes in western North America. In the presence of larvae of its natural mosquito host, *Ae. sierrensis*, free-living *L. clarki* trophonts transform into parasitic cells (theronts) that form invasive cysts on the larval cuticle. Ciliates penetrate, multiply within, and ultimately kill the host. Specific laboratory objectives of the research summarized in this report were to continue the improvement of *in vitro* culturing techniques and to examine the fate of parasites introduced into artificial treeholes with larval populations under various conditions. Field results revealed that one year after release *L. clarki* was recovered in 40% of 25 treeholes, and that at two years post-release, *L. clarki* was found in 7 of 10 treeholes that were positive in 1987; two holes were dry and one was lost.


Jack Kelly Clark

Deer head effigy and CO_2 tank used by UC Berkeley entomologists to attract and trap ovipositing flies, April 1996

2015. Anderson, John R. 1989. **Use of deer models to study larviposition by wild nasopharyngeal bot flies (Diptera: Oestridae).** J. Med. Entomol. 26(3):234-236.
Abstract: Deer models baited with CO_2, and with CO_2 plus 1-octen-3-ol and Deer Trail Scent attracted and induced female *Cephenemyia apicata* and *C. jellisoni* to larviposit on them. Larvae were not deposited on unbaited models. Females of both species were seen at baited models, and an insect trapping adhesive applied to the nostrils, muzzle, and lips of models revealed that all larvae were stuck to the lips and bottom part of the muzzle. The models also attracted and caught most other parasitic *Diptera* known to attack black-tailed deer (*Odocoileus hemionus columbianus*) in the study areas.

2016. Anderson, John R., David R. Mercer, and Jan O. Washburn. 1989. **The character of compounds that mediate *Lambornella clarki* parasitism of *Aedes sierrensis* larvae.** Mosquito Control

Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 42-43.
Abstract: Free-living populations of the protozoan *Lambornella clarki* (Ciliophora: Tetrahymenidae) respond to the threat of predation by *Aedes sierrensis* larvae when the two species share treehole habitats. Part of the protozoan population changes morphologically and behaviorally to a form that can parasitize mosquito larvae. This formation of parasitic forms is irreversible, and the protozoa die if they cannot find suitable hosts. In a series of laboratory experiments, we have previously demonstrated that this transformation to the parasitic form is mediated by a waterborne induction cue that is apparently released by larvae during feeding. The cue does not persist for long after larvae stop feeding, and the amount of cue that forms is a function of the temperature and the larval feeding substrate. An important finding was that the induction response was proportional to larval density and thus to the concentration of the induction cue; more larval feeding results in more transformed *L. clarki* seeking and parasitizing mosquito hosts. The objectives in this study included further characterization and identification of the induction cue and isolation of cuticular compounds that mark *Ae. sierrensis* larvae as suitable hosts. It was noted that early in the rainy season, *L. clarki* do not rely on the induction cue; the initial round of larval attack is apparently a programmed behavior of at least some ciliates escaping their desiccation-resistant cysts.

2017. Anderson, John R., and Jan O. Washburn. 1989. **Field release, persistence, and impact of *Lambornella clarki* on natural populations of *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 53-55.
Abstract: *Lambornella clarki*, a tetrahymenid ciliate, is an endemic, facultative parasite of the western treehole mosquito, *Aedes sierrensis*. The objectives of this research were 1) to assess the persistence of the *L. clarki* we had previously released into natural treehole breeding sites of *Ae. sierrensis*, and 2) to quantify the impact of ciliate enzootics in laboratory and field populations of the mosquito. The parasite *L. clarki* was released into about 80 treeholes in Mendocino, Fresno, Marin, Orange, and San Diego counties. The success of these introductions varied; we found the parasite consistently for several years after release at some sites, while at others we were unable to recover it as soon as a week after introduction. Overall, the parasite recovery rate continues to average about 40% between years. We achieved the greatest success when releasing ciliates into water-filled treeholes in the spring after mosquitoes eclosed. Laboratory results suggest that low enzootic levels of *L. clarki* can reduce the number of mosquitoes emerging from a breeding site.

2018. Anderson, John R., and Jan O. Washburn. 1990. **Quantifying the impact of *Lambornella clarki* on larval population dynamics of *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 31-33.
Abstract: In laboratory microcosms with low-density host populations, survivorship of western treehole mosquitoes (*Aedes sierrensis*) to pupation was significantly lower for populations with *Lambornella clarki* parasites (48.4%) than for controls (64.5%). Survivorship to pupation was extremely low in high-density, food limited populations and there was no significant difference between survivorship of treatment and control populations. In experimental treeholes, average emergence success was lower for populations developing with *L. clarki* (28.5%, N=18); in those holes with ciliate enzootics only 29.3% (N=16) of larvae completed development compared to 41.0% (N=14) for control populations. A total of 10.3% of the adults emerging from *L. clarki* holes also were infected. Because female mosquitoes infected with *L. clarki* neither seek blood meals nor lay eggs, the realized fitness and vector potential were even lower for larval populations with ciliates.

2019. Anderson, John R. 1991. **Arthropod parasites of deer at the UC Hopland Field Station.** Pp. 171-174 *in:* Proc. Columbian Black-Tailed Deer Workshop (R. H. Schmidt, R. M. Timm, G. A. Giusti, and P. J. Tinnin, compilers), Hopland Field Station Publ. 102, Univ. Calif., Hopland, CA.
Abstract: Studies at the Hopland Field Station have identified just over 50 species of insects and ticks that attack and feed on the Columbian black-tailed deer. Most are parasitic blood-sucking species that need a blood meal to provide the protein for egg production. In the course of feeding, several of these parasitic arthropods transmit various pathogens to deer. The relative seasonal abundance of these ectoparasites is summarized in a table. A selected bibliography of publications about arthropod parasites of deer is provided.

2020. Anderson, John R. 1991. **Larviposition by nasopharyngeal bot flies (Oestridae: Cephenemyia) (Abstract).** P. 5 *in:* Abstracts, 2nd Int. Congr. Dipterology, Bratislava, Czechoslovakia, Aug. 27 - Sept. 1, 1990, L'Udovit Weismann, I. Országh, and A. C. Pont (eds.), SPB Academic Publ., The Hague.
Abstract: The method of larviposition was studied by using deer and reindeer models baited with CO2, and CO2 and octenol, and by laboratory studies of females that were captured in CO2-baited insect flight traps. *Cephenemyia apicata*, *C. jellisoni*, and *C. trompe* were induced to larviposit on baited animal models exposed in the field; no larvae were deposited on unbaited models. Females of two species were seen at baited models, and an insect trapping adhesive applied to the nostrils, muzzle, and lips of models showed that all larvae of the three species were stuck to the lips and lower portion of the muzzle. When larvae extracted from live females were experimentally placed on surfaces treated with adhesive, most remained where placed; others crawled for only a few millimeters before becoming permanently immobile. Results of all field exposures of deer models show that wild *Cephenemyia* females do not home in on the nostrils as a larviposition target. Also, the low numbers of larvae (10-75) found per day on models attacked by larvipositing females indicate that once a host is located, a fly usually attacks only once, or rarely, twice. Such behavior would ensure the distribution of progeny among many hosts. Females electrostimulated in the laboratory either forcefully sprayed groups of larvae from 5-20 cm in tiny droplets or uterine fluid (*C. jellisoni* and *C. trompe*), or they expelled one large drop of sticky uterine fluid (*C. apicata*) that adhered to the gonopore and usually contained about 40 larvae. Dissections of females caught at mating sites revealed that they contain about 1,000 eggs that later hatch in the uterus. Study of dissected females revealed that the number of larvae expelled with each larviposition was controlled by a utero-vaginal valve located between the uterus and the opening of the vagina. When the larvipositor is in the relaxed, withdrawn position, larvae move from the uterus into the vagina through the opened valve; as the larvipositor is extended during larviposition the U-V valve closes. The closed valve blocks the opening into the vagina and prevents additional larvae from entering. With the U-V valve in the closed position, larvae in the lumen of the vagina are extruded under pressure as the larvipositor is extended to its maximum length.

2021. Anderson, John R., and Jan O. Washburn. 1991. **Life cycle and impact of the pathogen, *Lambornella clarki* (Ciliophora: Tetrahymenidae) on the western treehole mosquito, *Aedes sierrensis* (Diptera: Culicidae) (Abstract).** P. 6 *in:* Abstracts, 2nd Int. Congr. Dipterology, Bratislava, Czechoslovakia, Aug. 27 - Sept. 1, 1990, L'Udovit Weismann, I. Országh, and A. C. Pont (eds.), SPB Academic Publ., The Hague.
Abstract: Field and laboratory studies revealed that the life cycle of *Lambornella clarki* is closely synchronized with that of its natural

host, *Aedes sierrensis*. In the Mediterranean climate of northern California, where most treehole breeding sites remain dry for 5-6 months, *Ae. sierrensis* survives the dry season in the desiccation-resistant egg stage, and *L. clarki* in the desiccation-resistant cyst stage. First instar larvae of *Ae. sierrensis* and motile ciliates of *L. clarki* appear in water samples within 24 hrs after winter rains begin to fill treeholes. Our studies revealed that *L. clarki* is a facultative parasite capable of causing extinction of resident mosquito populations. Larval populations are reduced or eliminated by multiple parasitic cycles that occur over the prolonged period of larval development. A unique behavioral response of *L. clarki* is that it responds to the threat of larval predation by transforming from a free-living to a parasitic form. In the presence of a water-borne factor from predaceous, filter-feeding mosquito larvae, the free living, bactivorous trophont transforms into a host-seeking, parasitic theront that invades and kills mosquito larvae. Almost all infected larvae die within three weeks, but when late instar larvae are infected many survive to eclose as adults. About 13% of field-eclosed adults have been infected. Because females infected with *L. clarki* are parasitically sterilized and inhibited from host seeking/blood feeding, they are functionally removed from the biting and reproducing population. Infected adults serve as the dispersal agents of *L. clarki* when they die and decompose in treeholes, and when infected females behave like gravid females, but deposit ciliates instead of eggs. Naturally-established populations of *L. clarki* have show less than a 2% turnover per year in parasite extinction and colonization rates. Following development of in vitro culture techniques, laboratory-reared cultures have been experimentally introduced into *L. clarki*-negative treeholes throughout California. Through 1989, *L. clarki* has been established in about 40% of the negative treeholes. Based on recovery of infected larvae and/or tree swimming ciliates, its persistence in these treeholes has exceeded 80% over three years. In various treeholes monitored for several years the total larval mortality plus adult infection ranged from about 15 to 65%. In about 10% of the occupied treeholes, *L. clarki* eliminated resident larval populations.

2022. Anderson, John R., and Jan O. Washburn. 1991. **Quantifying the impact of *Lambornella clarki* on larval population dynamics of *Aedes sierrensis*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 33-35.

Abstract: Previous studies show that at certain larval densities, low infection levels in populations can significantly reduce the number of adult mosquitoes emerging. We have sought to study the impact and biological control potential of the ciliate *Lambornella clarki*, an endoparasite of the western treehole mosquito, *Aedes sierrensis*. Secondly, we wished to measure various biotic and abiotic characteristics of natural treeholes and to correlate these attributed with populations of emerging mosquitoes. Because treeholes are extremely heterogenous habitats, it is important to identify those factors that define habitat quality and determine mosquito productivity. Results from the laboratory microcosm study evaluating the effects of *L. clarki* enzootics on populations developing under three nutrient regimes corroborate those from previous experiments, in which we found differential effects of parasitism among treeholes with different larval densities. Infected populations developing under medium and high nutrient conditions produced significantly fewer adult mosquitoes than uninfected control populations. Mortality from *L. clarki* was density-dependent, since the parasite selectively reduced host survival in the treatment where the potential for mosquito production was the greatest. Data suggest that the impact of *L. clarki* in natural treeholes can be modified by abiotic factors such as the pattern of precipitation. During the first 10 weeks of the experiment, differences between sizes of surviving mosquito populations with and without *L. clarki* were similar for each food treatment because the cumulative effects of several parasite cycles were comparable. As the season progressed, however, food limitation became an important regulatory factor for populations in the low and medium food treatments, and parasitism was less important. The role of parasitism declines, in part, because larvae shift their feeding behavior from browsing to filter-feeding in response to the scarcity of food; in doing so they also increase their rate of feeding on the free-swimming and infective stages of *L. clarki*, which reduces the efficiency of horizontal transmission. In high food treatments, where cumulative mortality by *L. clarki* was not compensated for by starvation, parasitism remained the dominant mortality factor for host populations and, ultimately, fewer mosquitoes survived to adulthood than in controls. These data suggest that if treeholes are inundated during late winter or early spring, the larval tenure may be shortened to only a few months, and the impact of *L. clarki* will be more uniform because the role of starvation as a regulatory force will be reduced.

2023. Anderson, John R., and Jan O. Washburn. 1992. **Correlating emergence of *Aedes sierrensis* with treehole characteristics.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 44-46.

Abstract: To further evaluate the potential of *Lambornella clarki*, a facultative protozoan parasite of the western treehole mosquito *Aedes sierrensis*, as a biological control agent, we studied the characteristics of individual treehole habitats. We monitored the characteristics and mosquito productivity of 46 treeholes at 3 field sites in Lake and Mendocino counties during 1992. Each hole was visited weekly between January and April, at which time we monitored water level, temperature, dissolved oxygen, electrical conductivity, and pH. Treehole water samples were analyzed for phenolic content, alkalinity, total organic carbon, total nitrogen, ammonium concentration, and color. In spring at the onset of pupation, an emergence trap was placed over each hole and adult mosquitoes were collected twice weekly until emergence ceased (Sept. 1). In a separate study, we quantified the loss of *Ae. sierrensis* immatures caused by habitat overflow from rainwater. A total of 12,136 adult mosquitoes were collected from emergence traps, and the numbers emerging from individual treeholes varied greatly. Based on estimates of maximum treehole volume, productivity ranged from 0.002 to 1.056 adults/ml of treehole water. Two hypotheses could explain this variability: 1) there are probably qualitative differences among treeholes which make some habitats better for larval development than others; and 2) since treeholes may vary in their attractiveness to female mosquitoes, some holes may simply receive more eggs than others. A simple correlation matrix incorporating all treehole characteristics measured revealed no single physical or chemical factor that correlated significantly with mosquito productivity. Some factors were significantly correlated with each other, and some (e.g. water color) may be of some predictive value for gauging treehole productivity. We are currently using multiple regression models to further analyze data, and we have designed further laboratory experiments. Results demonstrate that rainfall overflow can be a significant, but apparently overlooked, source of catastrophic mortality for larval mosquito populations. This process may vary from year to year and may be difficult to predict. On the other hand, toxic effects from chemical constituents of treehole water and the impact of natural enemies may be amenable to modeling.

2024. Anderson, John R., and Eveline U. Hartmann. 1993. **A survey of northern California treeholes. Do treehole characteristics correlate with emerging *Aedes sierrensis*?** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 26-27.

Abstract: The western treehole mosquito, *Aedes sierrensis*, readily attacks people and is the main vector for canine heartworm in California. It is the primary mosquito found developing in most natural treeholes in California's woodlands. The numbers and sizes

of *Ae. sierrensis* emerging from individual treeholes vary significantly. The purpose of this survey was to determine if various biotic and/or abiotic factors correlated with adult mosquito production and size in different treeholes. Data were collected in 1992 while surveying 48 treeholes located at the Hopland Research & Extension Center and at two sites in Lake Co., California. During larval development, temperature, water level, electrical conductivity, pH, and dissolved oxygen of each treehole were recorded. Chemical analyses were performed on water samples collected on three dates during the 1991-92 rainy season– Feb. 5-6, Feb. 17-18, and Apr. 28-29. The chemical analyses included total phenolic determination, total organic carbon, NH_4+, Kjeldahl nitrogen, alkalinity, color, and bacterial count. During March and April, traps were placed over treehole openings in order to retain emerging adults, and adult mosquitoes were collected two times per week. We found great variation among the parameters we measured for the treeholes, with large ranges for most chemical parameters. In summary, the chemical constituents we measured from water samples did not explain the variation in adult emergence. Thus, variation in adult production may be due to other factors such as preferential oviposition among breeding sites, habitat overflow, or water quality parameters that we did not measure. These factors may affect larval development and/or survival and are currently being investigated in laboratory and field studies.

Eveline Hartmann

UC Berkeley researcher Jan Washburn labels mosquito larvae collected from water-filled treehole as part of a study to identify and monitor mosquito parasites and pathogens, Summer 1991

2025. Anderson, John R., and W. L. Yee. 1995. **Trapping black flies (Diptera: Simuliidae) in northern California. I. Species composition and seasonal abundance on horses, host models, and in insect flight traps.** J. Vector Ecol. 20(1):7-25.
Abstract: Catches of black flies (Diptera: Simuliidae) on CO_2-baited three-dimensional horse/cow models with adhesive-treated ears and bodies, and in CO_2-baited insect flight traps, accurately reflected the species composition and relative seasonal densities of 4 of 5 species caught attacking free-ranging horses in northern California. On host models, the specific ear-landing site behavior of *Simulium argus*, members of the *Simulium vittatum* complex, and *Simulium virgatum* complex was the same as that observed on pastured horses. However, although both *Simulium griseum* and *Simulium trivittatum* were caught feeding almost exclusively on the undersides of horses, both were caught in large numbers on the ears of animal head models, even when a head model was accompanied by a body model. The large numbers of *S. argus* collected on ears of CO_2-baited horse head models and CO_2-baited insect flight traps, and the small numbers concurrently collected from the ears of horses, suggest that horses are not a preferred host, and that they may even be repellent for this species. During concurrent periods of study the observed landing rates of *S. argus/S. vittatum* on horses' ears exceeded catch rates on the adhesive-treated ears of horse head models by 2X to 5X. This discrepancy was related to the ear flicking behavior of horses, which often resulted in multiple landings by dislodged flies. On models, all species located the ears whether CO_2 was released from the front of the head or below the body. The large peaks in numbers of several black fly species attacking horses and caught by models and traps during September, October, and November revealed a previously unrecognized problem in northern California.

2026. Ayala, Stephen C. 1970. **Protozoan parasites associated with California sandflies.** Ph.D. Dissertation, Univ. Calif. Berkeley. 99 pp.
Abstract: Recent studies on the bionomics of phlebotomine sandflies in California stimulated this investigation of their associated protozoan parasites. The known California sandfly species breed in rodent burrows and use reptiles and amphibians as hosts. Several blood parasites from these cold-blooded vertebrates use sandflies as intermediate hosts. This investigation has implicated sandflies in the life cycles of a saurian malarial parasite, *Plasmodium mexicanum*; hemogregarines of the genus *Hepatozoon*; an unnamed acephaline gregarine of the genus *Lankesteria*; and trypanosomes from the California toad, the western fence lizard, and the southern alligator lizard. No monoxenous flagellates were encountered. *Plasmodium mexicanum* was found in fence lizards throughout much of central California, from Riverside to Mendocino Counties and in both the Coastal and Sierra Nevada foothill mountain ranges. It has also been found infecting sagebrush lizards and southern alligator lizards. Its geographical and reproductive isolation from the type population near Mexico City prompted description of the parasite as a distinct strain. It undergoes a seasonal relapse as infected lizards emerge from hibernation. The complete extrinsic cycle was followed in *Lutzomyia vexatrix occidentis* and *Lu. stewarti*, salivary glands as with mosquito-borne species of the genus *Plasmodium*. Sporozoites from *Lu. v. occidentis* produced infections in laboratory-reared fence lizard hatchlings. *Hepatozoon* species hemogregarines are common in central California reptiles and extrinsic stages were frequently encountered in wild sandflies. Oocysts sometimes filled every available space in the insect's hemocoel. Sporozoites from these flies produced patent infections within 23 days in a rattlesnake, a kingsnake, garter snakes, a racer, southern alligator lizards and western fence lizards. Acephaline gregarines of the genus *Lankesteria* were often found infecting the hemocoel and accessory glands of *Lu. v. occidentis*. The gregarine's sexual cycle occurred only in female sandflies that had initiated an ovarian cycle. Infection does not interfere with the use of the accessory glands for distinguishing parous female sandflies. *Trypanosoma bufophlebotomi* of California toads develops intense posterior hindgut infections in *Lu. v. occidentis*. Transmission involves ingestion of infective sandflies. *Trypanosoma scelopori* of fence lizards appears structurally different in alligator lizards, from which it is described here as *T. s.* var. *gerrhonoti.* Sandfly infections from both lizard species are identical, with long, thin epimastigotes colonizing the anterior midgut. These forms produced patent infections in alligator lizard hatchlings following syringe transfer. These natural cycles well illustrate many concepts of landscape epidemiology, and the association with rodent burrows parallels sandfly-borne disease patterns in several other parts of the world.

2027. Ayala, Stephen C. 1970. **Lizard malaria in California; description of a strain of *Plasmodium mexicanum*, and biogeography of lizard malaria in western North America.** J. Parasitol. 56(3):417-425.

Abstract: A California strain of *Plasmodium mexicanum* is described, allopatric to the type population in central Mexico. Exoerythrocytic stages occur in vascular endothelial cells, in leucocytes (with a budding form), and free in the blood. The parasite is widespread in fence lizards (*Sceloporus occidentalis*) in California. A spring relapse occurs; at other times parasitemia consists mainly of mature gametocytes. Most transmission occurs in the late spring and early summer before hatchling lizards emerge. There is evidence of a *P. mexicanum*-like complex of lizard malarial parasites in western North America.

Jack Kelly Clark

Western fence lizard, the host of the parasite *Plasmodium mexicanum*, the causative agent of lizard malaria

2028. Ayala, Stephen C. 1970. ***Plasmodium mexicanum* in California: natural history and development in phlebotomine sandflies (Diptera: Psychodidae) (Abstract).** J. Parasitol. 56(4): 13.
Abstract: An epidemiological study was undertaken in California to discover the vector for lizard malaria (*Plasmodium mexicanum*), found to infect western fence lizards (*Sceloporus occidentalis*). Infected lizards were found only in the dry foothill country described as Upper Sonoran Zone or "Mediterranean" terrain, and below 1,200 m elevation. Infection patterns within the lizard population and through seasons are described. The range of phlebotomine sandflies was found to closely coincide with the distribution of infected lizards. Three species occur in the infection zone, and they inhabit the burrow systems of California ground squirrels, *Citellus beecheyi*, from which they emerge at night to feed upon reptiles and terrestrial amphibians. Fence lizards use the burrow systems as refuges, and sandflies probably have little difficulty in locating sleeping lizards at night. The developmental cycle of lizard malaria in two species of sandflies is described elsewhere.

2029. Ayala, Stephen C. 1970. **Two new trypanosomes from California toads and lizards.** J. Protozool. 17(3):370-373.
***Abstract*:** *Trypanosoma bufophlebotomi* n. sp. and *T. scelopori* n. sp. are described from the California toad *Bufo boreas halophilus* and the western fence lizard *Sceloporus occidentalis,* respectively. *T. bufophlebotomi* occurred in 15% of 39 toads examined and is characterized by a juxtanuclear, bipolar-staining kinetoplast. The parasite may share a common ancestry with another sandfly-transmitted trypanosome of toads from China. *T. scelopori* occurred in 0.4% of 758 lizards examined for malarial parasites. It may also develop in sandflies.

2030. Ayala, Stephen C., and Dwayne Lee. 1970. **Saurian malaria: development of sporozoites in two species of Phlebotomine sandflies.** Science 167:891-892.
Abstract: Sporozoites of a lizard malaria parasite, *Plasmodium mexicanum*, developed in 2 species of sandfly, *Lutzomyia vexatrix occidentis* and *L. stewarti*. Salivary glands were infected 11 days after the flies took an infective blood meal. This is the first report of a malaria parasite undergoing sporogonic development in an insect other than a mosquito and the first description of lizard malaria sporogenesis.

2031. Ayala, Stephen C. 1971. **Gregarine infections in the California sandfly.** J. Invert. Pathol. 17(3):440-441.
Abstract: Previous reviews of the genus *Lankesteria* have not considered acephaline gregarines of New World phlebotomine sandflies. Infected California sandflies, *Lutzomyia vexatrix occidentis*, were collected in Mendocino and Monterey counties during 1967-1970. Apparently, onset of the female's ovarian cycle stimulates the gregarine's sexual cycle. Gamonts in syzygy, immature gametocysts, and gametocysts replete with oocysts occurred only in female sandflies that had taken a blood meal, initiating their gonadotrophic cycle. Host hormonal control over an acephaline gregarine's sexual cycle has not been suggested previously.

2032. Baker, Norman F., William M. Longhurst, Donald T. Torell, and William C. Weir. 1954. **Preliminary studies of parasitism in sheep on rangelands.** Am. J. Vet. Res. 15(56):356-360.
Abstract: A study of parasitism as it occurs in sheep on the Hopland Field Station is reported. *Ostertagia circumcincta* is the most common stomach worm, while *Trichostrongylus vitrinus*, *Nematodirus filicollis*, and *N. spathiger* are the most common parasites of the small intestine. Individual lambs showed a very marked difference in the total worm counts but the percentage of species and sexes was surprisingly constant. Phenothiazine as employed in this experiment was totally ineffective against nematodes present in the gastrointestinal tracts of lambs. In view of the evidence presented, we conclude that this was due possibly to the high percentage of large particle sizes in the phenothiazine used.

2033. Baker, Norman F., William M. Longhurst, and James R. Douglas. 1957. **Experimental transmission of gastrointestinal nematodes between domestic sheep and Columbian black-tailed deer.** Trans. N. Am. Wildl. Conf. 22:160-168.
Abstract: A series of experiments were conducted to determine the transmissibility of gastrointestinal nematodes from sheep to sheep, from sheep to deer, and from deer to sheep. The data indicates that when larvae cultured from deer feces are inoculated into sheep, and when larvae cultured from sheep feces are inoculated into deer, there is a significant decrease in the number of parasites which reach maturity as compared with inoculations of larvae from an homologous source. This partial host specificity was more marked in the genus *Ostertagia* than in the genera *Trichostrongylus* and *Nematodirus*.

2034. Baker, Norman F., P. H. Allen, William M. Longhurst, and James R. Douglas. 1959. **A comparison of the anthelmintic efficiency of purified and N.F. phenothiazine.** Am. J. Vet. Res. 20(75):409-413.
Abstract: In attempting to develop a more efficacious formulation and account for anthelmintic failures of phenothiazine, the authors conducted intensive trials on the influence of particle size and purity on anthelmintic efficiency of phenothiazine. The anthelmintic efficiency of purified phenothiazine preparations having a mean particle diameter of 14.5μ and 6.6μ were compared with preparations of N.F. phenothiazine having mean particle diameters of 10.0μ and 2.6μ. Trials were conducted in sheep with naturally acquired worm infections and in laboratory mice experimentally infected with *Nematospiroides dubius*. The purified material of 6.6μ mean particle diameter (specific surface 6,940 cm^2/gm) gave comparable results to an N.F. phenothiazine preparation having a mean particle diameter of 2.6μ specific surface 17,480 cm^2/gm). The purified material having a

mean particle diameter of 14.4μ (specific surface 3,312 cm^2/gm) was only slightly less efficient than that having a mean particle diameter of 6.6μ and the N.F. preparation having a mean particle diameter of 2.6μ, but was markedly more efficient than the N.F. phenothiazine having a mean particle diameter of 10.0μ (specific surface 4,412 cm^2/gm). All preparations were more efficient against species of worms occurring in the abomasums than against those in the small intestines of sheep.

2035. Baker, Norman F., and James R. Douglas. 1962. **Critical trials with thiabendazole as an anthelmintic in the gastrointestinal tract of cattle and sheep.** Am. J. Vet. Res. 23(97): 1219-1223.
Abstract: Thiabendazole was found to remove 82% of *Ostertagia* spp. and 98% of *Trichostrongylus* spp. from the abomasum of cattle at a dosage level of 50 mg/kg of body weight. At 100 mg/kg of body weight, 96% of *Ostertagia* spp. and 100% of *Trichostrongylus* spp. were removed. In the small intestine, 50 mg/kg of body weight was only 36% efficient against *Cooperia* spp. At 100 mg/kg of body weight, the drug removed 91% of *Cooperia* spp. At a level of 29 mg/kg of body weight in lambs, anthelmintic efficiency in the abomasum was 85% against *Ostertagia* spp. and 89% against *Trichostrongylus* spp. In the small intestine, however, this level resulted in inadequate anthelmintic activity against *Trichostrongylus* spp. and *Nematodirus* spp.

2036. Baker, Norman F., R. A. Fisk, and James R. Douglas. 1970. **A study of *dl*-tetramisole in lambs: anthelmintic efficacy and toxicity.** Am. J. Vet. Res. 31(6):977-980.
Abstract: The wide-spectrum anthelmintic *dl*-tetramisole was evaluated in a controlled anthelmintic trial in lambs harboring naturally acquired gastrointestinal nematodes. Given at dose rates of 5 mg of *dl*-tetramisole/kg of body weight, 10 mg/kg, and 15 mg/kg, anthelmintic efficacies against *Ostertagia circumcincta* in the abomasum were 68%, 89%, and 99% respectively. Against *Trichostrongylus axei* in the abomasum, the efficacies were 82%, 98%, and 99%. The same dose rates removed 72%, 97%, and 99% of *Trichostrongylus* spp. in the small intestine and 90%, 99%, and 99% of *Nematodirus* spp. From results of studies on the acute oral toxicity, it was concluded that the minimal toxic dose rate for *dl*-tetramisole was 2 to 3 times that of the therapeutic dose rate.

2037. Baker, Norman F., and R. A. Fisk. 1977. **Anthelmintic efficiency of oxfendazole in California lambs.** Am. J. Vet. Res. 38(9):1315-1316.
Abstract: Oxfendazole, methyl 5(6)-phenylsulfinyl-2-benzimidazole carbamate, was given by oral drench (5 mg/kg) to California lambs harboring natural infections of gastrointestinal nematodes. Ninety-nine percent of adult *Ostertagia circumcincta, O. trifurcata, Trichostrongylus axei, T. vitrinus, T. colubriformis, Nematodirus filicollis*, and *N. spathiger* were removed by the anthelmintic.

2038. Baker, Norman F., and R. A. Fisk. 1980. **Influence of plasma A esterase in anthelmintic action of haloxon in sheep.** Am. J. Vet. Res. 41(11):1854-1856.
Abstract: Controlled trials were conducted to evaluate the anthelmintic action of haloxon in two phenotypes of lambs, one having an A esterase in plasma which rapidly hydrolyzes di-(2-chloroethyl)aryl phosphates and the other without this enzyme. A total of 116 lambs, 57 with and 59 without the plasma A esterase, 6 to 9 months old, harboring naturally acquired nematode infections were used in 3 trials. Haloxon was administered orally at 20, 25, and 35 mg/kg of body weight. Nematodes against which haloxon was evaluated in the abomasum were *Ostertagia circumcincta* and *Trichostrongylus axei* and in the small intestine were *T. vitrinus, T. colubriformis, Nematodirus spathiger* and *N. filicollis*. The anthelmintic efficiency of haloxon did not differ in the two phenotypes of sheep.

2039. Baker, Norman F., R. A. Fisk, and C. Stormont. 1980. **Acute oral median lethal dose of haloxon and coumaphos in sheep as influenced by plasma A esterase.** Am. J. Vet. Res. 41(11):1857-1859.
Abstract: Determination of the acute oral median lethal dose (LD_{50}) of haloxon for lambs classified as to the presence or absence of plasma esterases (A esterase; EsA) rapidly hydrolyzing haloxon revealed markedly different values for the two phenotypes of sheep. The LD_{50} for EsA- lambs was 763 mg/kg of body weight with 95% confidence limits of 543 to 1,072 mg/kg. The acute oral LD_{50} for EsA+ lambs remains undetermined but was demonstrated to be in excess of 11,392 mg/kg. The acute oral LD_{50} for a closely related organophosphate (coumaphos) was not different in the two phenotypes of sheep.

2040. Behymer, Darrell E., R. Ruppanner, Dale L. Brooks, J. C. Williams, and Charles E. Franti. 1985. **Enzyme immunoassay for surveillance of Q fever.** Am. J. Vet. Res. 46(11):2413-2417.
Abstract: An enzyme-linked immunosorbent assay (ELISA) was developed to monitor antibodies against *Coxiella burnetii* among animal populations used in research and teaching facilities. Various antigenic components of *C. burnetii* prepared from phase I and phase II whole cells and commercially available antigens were evaluated. A trichloroacetic acid extract was selected for routine use. There was a linear relationship between the transformed absorbance readings of the ELISA results and microagglutination (MA) titers. Comparison between positive or negative results of the MA test and ELISA gave 98.6% concordance. Using the MA test as the standard, ELISA results were 97.8% sensitive and 100% specific. The efficacy of ELISA was evaluated by testing ruminants with known histories of *C. burnetii* infection. Antibody prevalence was 0 in 117 sheep with no history of *C. burnetii* infection, 22% in 145 naturally infected sheep used for research, and 53% in 115 sheep used for vaccine field trials. Forty-eight percent of 120 dairy cows and 52% of 79 goats from endemically infected herds were seropositive. These results indicate that ELISA should be the test of choice for mass screening and surveillance of animals when Q fever is a suspected biohazard.

2041. Bromwich, Carl R., and Jos. J. Schall. 1986. **Infection dynamics of *Plasmodium mexicanum*, a malarial parasite of lizards.** Ecology 67(5):1227-1235.
Abstract: A mark-recapture technique was used to evaluate variation in the course of infection of the malarial parasite, *Plasmodium mexicanum*, in its natural host, the western fence lizard, (*Sceloporus occidentalis*) during the warm season in northern California. These data were used to examine the hypothesis that the parasite modifies its reproductive schedule during the year to meet the challenges of a seasonal environment. Infections first became evident in the blood at various times during the warm season (May-September), then rose exponentially before leveling off to a constant parasite load. Parasite levels (parasitemia) declined during winter, but rebounded rapidly the next spring, apparently once again to a steady level. Most infections studied were older ones remaining at a relatively constant level throughout the warm season. Exponential growth rate of rising infections varied over a 4-fold range, and chronic infections varied greatly in parasitemia (over 2 orders of magnitude). The end of exponential growth, and the ultimate parasitemia level reached, were related to the timing of production of gametocytes (nondividing sex cells). Gametocytes appeared very early in an infection, then increased so that they eventually dominated the parasite population. The rate of increase of gametocytes varied greatly among infections, but was not clearly related to host age or to date the infection originated. Weak evidence suggests that the rate of sexual proliferation was more rapid in infection originating late in the warm season. Neither host sex nor age was associated with rate of parasite

increase in growing infections. Maximum parasitemia was independent of sex or starting date of the infection, but was higher in juveniles than in adults. We conclude that during the warm season, the schedule of reproductive activities of *P. mexicanum* does not follow precisely the time of year or host quality, perhaps because of the developmental mechanism driving gametogenesis.

2042. Brooks, Dale L. 1981. **Q-fever (Abstract).** *In:* 32nd Ann. Session, Am. Assoc. for Laboratory Animal Sci., Publ. 81-3, American Assoc. for Laboratory Animal Sci., Salt Lake City, UT, Sept. 20-25.
Abstract: The historical aspects of Q-fever, the characteristics of *Coxiella burnetii*, the epizootiology, methods of diagnosis, and controlling the disease in man, domestic animals, and wildlife as these subjects relate to vivariums are discussed. The epidemiology and control measures in the urban University of California at San Francisco Medical School in the spring of 1979 including 88 cases and one death are reviewed. Another outbreak in 1980 at the University of Colorado Medical School, with at least 29 confirmed positive cases in man probably due to changes in animal procurement procedures, is covered. These experiences illustrate the hazards to individuals in contact with experimental sheep. While transmission to man is haphazard, attack rates can be high even in low exposure situations. Sheep and laboratory isolation areas will diminish outside transmission but leaves "insiders" heavily at risk. Vaccination in man has been successful but is associated with adverse local reactions; this reaction can be minimized by screening skin tests. An IND status phase I Q-fever vaccines, serologic, skin tests, and cellular immunologic studies will be presented for their potential use in "at risk" personnel.

2043. Brown, Richard N., and Robert S. Lane. 1992. **Lyme disease in California: a novel enzootic transmission cycle of *Borrelia burgdorferi*.** Science 256:1439-1442.
Abstract: Knowledge of zoonotic transmission cycles is essential for the development of effective strategies for disease prevention. The enzootiology of Lyme disease in California differs fundamentally from that reported from the eastern United States. Woodrats, not mice, serve as reservoir hosts, and *Ixodes neotomae*, a nonhuman-biting tick, maintains the agent of Lyme disease, *Borrelia burgdorferi*, in enzootic cycles. The western black-legged tick, *Ixodes pacificus*, is the primary vector to humans, but it appears to be an inefficient maintenance vector. Isolates of *B. burgdorferi* from California exhibit considerable antigenic heterogeneity, and some isolates differ strikingly from isolates recovered from this and other geographic regions.

2044. Brown, Richard N., and Robert S. Lane. 1994. **Natural and experimental *Borrelia burgdorferi* infections in woodrats and deer mice from California.** J. Wildl. Dis. 30(3):389-398.
Abstract: Sequestration of spirochetes and concurrent histopathologic lesions were evaluated in tissues of *Borrelia burgdorferi*-infected dusky-footed woodrats (*Neotoma fuscipes*) and deer mice (*Peromyscus maniculatus*). Rodents were either wild-caught and naturally infected or were experimentally infected by tick bite, by intramuscular (i.m.) injection of cultured spirochetes, or by i.m. injection of tick suspensions. Samples of host tissues, including skin, blood, ear, brain, eye, heart, lung, liver, spleen, kidney, and urinary bladder, were removed from up to 21 woodrats and 4 deer mice and cultured in BSK II medium. Borreliae-positive cultures of ear punch biopsies were obtained from 10 of 11 woodrats and from all of 4 deer mice. Additionally, positive cultures were obtained from 3 of 36 skin biopsies of woodrats and from 1 of 36 cultures of woodrat blood. In contrast, spirochetes were not observed in 505 cultures of internal organs or whole blood. Samples of tissues from 7 naturally infected woodrats, 4 experimentally infected woodrats, and 9 experimentally infected deer mice also were examined for histopathologic lesions. Nonsuppurative cellular infiltrates were recognized in samples from most tissue types from woodrats, but few lesions were observed in tissues from deer mice. Recognized lesions in woodrats that were consistent with infections of Lyme borreliosis in other species included synovitis, myositis, and myocarditis. Such lesions were more common in woodrats than in deer mice. Inflammatory lesions, especially synovitis, were more common in woodrats with long-term infections than in woodrats with relatively short-term infections. No clinical signs of disease were observed in either species of rodent.


Jack Kelly Clark

Field lab for UC Berkeley researcher Bob Lane's ecologic studies on tick-vectored diseases, Orchard Pasture, April 1996

2045. Brown, Richard N., and Robert S. Lane. 1996. **Reservoir competence of four chaparral-dwelling rodents for *Borrelia burgdorferi* in California.** Am. J. Trop. Med. Hyg. 54(1):84-91.
Abstract: Aspects of the reservoir competence of 4 rodents for the Lyme disease spirochete, *Borrelia burgdorferi*, were evaluated in California. Rodents were live-trapped and ear-punch biopsies were cultured during each season. A second set of biopsies was cultured from representative individuals after 2-3 weeks of captivity and the results of culturing biopsies taken on both dates were compared with the results of feeding *Ixodes pacificus* larvae on hosts xenodiagnostically. The prevalence of infections did not differ significantly between dusky-footed woodrats (*Neotoma fuscipes*) and California kangaroo rats (*Dipodomys californicus*) nor among seasons. Combined results of the 3 tests showed that 85.7% of dusky-footed woodrats (n = 21) and 78.6% of California kangaroo rats (n = 14) were infected with *B. burgdorferi*. In contrast, only 22.2% of brush mice (*Peromyscus boylei*) (n = 14) and 7.1% of piñon mice (*P. truei*) (n = 9) were infected. The sensitivity of culturing ear-punch biopsies as an assay for borrelial infection was significantly greater when biopsies were taken after a short period of captivity (0.89) rather than on the day of capture (0.52). Tick xenodiagnosis, in which *I. pacificus* was used as the vector, revealed borrelial infections in 90.3% of infected rodents. Spirochetes were observed in 37.7% of 239, 45.2% of 155, 60.0% of 10, and 7.1% of 14 cultures of nymphal *I. pacificus* fed as larvae on naturally infected woodrats, kangaroo rats, brush mice, and a piñon mouse, respectively. The mean prevalence of infection in xenodiagnostic ticks varied significantly among host species with a greater proportion of ticks infected while feeding on woodrats and kangaroo rats than on mice. This study reconfirms previous reports that implicated woodrats and kangaroo rats as reservoirs of *B. burgdorferi* in California.

2046. Burgdorfer, Willy, Robert S. Lane, Alan G. Barbour, Robert A. Gresbrink, and John R. Anderson. 1985. **The western black-legged tick, *Ixodes pacificus*: a vector of *Borrelia burgdorferi*.** Am. J. Trop. Med. Hyg. 34(5):925-930.
Abstract: To determine the significance of the western black-legged

tick, *Ixodes pacificus*, a vector of the Lyme disease spirochete, *Borrelia burgdorferi*, a tick/spirochete survey was conducted in northern California and southwestern Oregon from 1982 to 1984. Of 1,687 adult ticks collected off vegetation, 25 (1.48%) contained spirochetes. Of 715 ticks from Oregon, 14 (1.96%) were infected whereas 11 (1.13%) of 972 ticks from California harbored spirochetes. An isolate of one of the spirochetes reacted specifically when treated with monoclonal antibodies to *B. burgdorferi*. Polyacrylamide gel electrophoresis of a lysate of the isolate showed it to be nearly identical with 2 isolates of *B. burgdorferi*. Of the 25 infected *I. pacificus*, 17 had spirochetes in their midgut only; the remaining 8 ticks showed a generalized infection of all the tissues, with midgut, central ganglion, and ovary or testes showing heavy spirochetal infections. Decreased immunofluorescent staining reactivity of spirochetes in tissues other than midgut in 6 of 8 *I. pacificus* with generalized infection may reflect adverse physiologic conditions for the development of spirochetes in the hemocele.

2047. Cappucci Jr., D. T., and William M. Longhurst. 1972. **Rabies in a deer.** Calif. Fish and Game 58(2):141-144.
Abstract: Rabies was diagnosed in a Columbian black-tailed deer (*Odocoileus hemionus columbianus*) from Yorkville, Mendocino County. Two persons subsequently received postexposure antirabies treatment. This is California's fifth reported episode of rabies in deer.

2048. Chaniotis, Byron N., and John R. Anderson. 1967. **Age structure, population dynamics and vector potential of *Phlebotomus* in northern California. Part I. Distinguishing parous from nulliparous flies.** J. Med. Entomol. 4(3):251-254.
Abstract: Of all internal organs examined, the accessory glands proved the most reliable and practical structures for distinguishing parous from nulliparous females of 3 species of *Phlebotomus* (*P. californicus, P. stewarti,* and *P. vexator occidentis*) in northern California. The appearance of granules in these glands was an unmistakable sign of a parous female. Only 3% of 300 blood-fed females had no granules in their accessory glands after oviposition. The rare mistaking of a parous specimen for a nullipar was the only error inherent in this technique, for accessory gland granules were not present in 150 nulliparous females examined. All 3 species were anautogenous and exhibited gonotrophic concordance.

2049. Chaniotis, Byron N., and John R. Anderson. 1968. **Age structure, population dynamics and vector potential of *Phlebotomus* in northern California. Part II. Field population dynamics and natural flagellate infections in parous females.** J. Med. Entomol. 5(3):273-292.
Abstract: The 3 known species of sandflies (*Phlebotomus californicus, P. stewarti,* and *P. vexator occidentis*) in California use burrows of the ground squirrel *Citellus beecheyi* as breeding and diurnal resting sites. In 1965 there were 3 annual field generations with adults being active from May - November. Their annual population peaked near the middle of this period and coincided with emergence of the second adult generation. Adults were primarily crepuscular and nocturnal in their above ground activities. While such activities were associated with dispersal, feeding, and probably mating, the results suggest that feeding and mating of flies also may occur within burrows during the day. Field capture of parous females showed that some flies survived long enough to take a second blood meal, but the the small percentages of such females captured also indicated the short duration of each generation's blood-sucking activities. Flagellate infections in only parous or gravid females of *P. v. occidentalis* strongly implies that this species serves as an intermediate host of a protozoan infecting one of its natural hosts. The presence of crithidial forms in the midgut indicates a trypanosome infection in the vertebrate host. Trypanosomes were not isolated from a number of reptiles examined, but all studies indicate that the most probably vertebrate host is a species of reptile or anuran on which these flies feed. As fly infections were confined to the posterior station, and because the females excrete small droplets from the anus while feeding, the vertebrate host must acquire its infection either by contamination of a wound or by ingesting infected flies.

Bot fly (*Cephenemyia* sp.) larvae infesting the retro-pharyngeal pouches of a black-tailed deer at Hopland

2050. Cogley, Thomas P., and John R. Anderson. 1981. **Invasion of black-tailed deer by nose bot fly larvae (Diptera: Oestridae: Oestrinae).** Int. J. Parasitol. 11(4):281-286.
Abstract: Invasion of black-tailed deer (*Odocoileus hemionus columbianus*) by larvae of the nose bot flies (*Cephenemyia apicata* and *C. jellisoni*) was investigated by observing their expulsion by larviparous females and their subsequent activity on the host. The drying uterine fluid encasing larvae (= larval packet) delays desiccation, ensures adhesion to hairs, and immediately dissolves upon contact with saliva. Contrary to the widely accepted nasal mode of invasion, larvae placed on muzzles of deer crawl ventrally toward the upper lip, enter the mouth, and then crawl caudally along the hard palate or tongue toward the throat. Hair located between the muzzle and nostril prevents larvae from entering the nostrils. A natural *per os* mode of invasion, heretofore unrecognized, is proposed. This is initiated by: 1) females depositing larval packets on the muzzle of the deer, or 2) deer licking larval packets from contaminated areas around the muzzle. The positive thermotropism of larvae is compatible with such a *per os* mode of entry into the host.

2051 Cory, J., C. E. Yunker, J. A. Howarth, Y. Hokama, L. E. Hughs, L. A. Thomas, and C. M. Clifford. 1975. **Isolation of spotted fever group and *Wolbachia*-like agents from field-collected materials by means of plaque formation in mammalian and mosquito cells.** Acta Virologica 19:443-445.
Abstract: Three isolations from ticks (*Dermacentor occidentalis*), collected at Hopland, California, of a rickettsia of the spotted fever group and 5 isolations from chipmunk (*Eutamias ruficaudus*) blood, collected in Montana, of a *Wolbachia*-like agent were obtained from plaques formed in Singh's *Aedes albopictu*s (mosquito) and Vero (African green monkey kidney) cell cultures. These organisms could not be isolated by injection of the infected ticks or blood into embryonated chicken eggs, guinea pigs, or voles (*Microtus pennsylvanicus*), but fluid cultures of Grace's *Antheraea eucalypti* (moth) and Singh's *A. albopictu*s cells inoculated with the bloods yielded the *Wolbachia*-like agent.

2052. Daly, Howell V. 1973. **Bees of the genus *Ceratina* in America north of Mexico (Hymenoptera: Apoidea).** Univ. Calif. Entomol. Pub. 74, pp. 1-113.
Abstract: Twenty-two species of small carpenter bees are described

for America north of Mexico. Of these, 6 are new taxa and 1 is a fossil from the Oligocene. A key to aid in the identification of recent species is provided and each species is described partly or entirely, together with distribution records and maps. Sample statistics have been computed for western species and an analysis made of the geographic variation of *Ceratina acantha*. Although polytypic taxa were recognized, subspecies were not designated because the phenetic relationships of the populations were complex. Evidence is presented that certain populations of *Ceratina acantha* in Los Angeles County are thelytokous. Among the western species, biological information is given for 8 and an attempt was made to evaluate the vegetation types most frequently inhabited.

2053. Daly, H. V., K. Hoelmer, and P. Gambino. 1991. **Clinal geographic variation in feral honey bees in California, USA.** Apidologie 22:591-609.
Abstract: Feral honey bees in California are mongrel populations, partially differentiated in morphometrics from managed colonies as well as from European subspecies. Most morphometric variables had low but significant correlations with environmental factors and clinal patterns of spatial autocorrelation with distance. Some measurements of body size exhibited Bergmann's Rule, but the hind legs did not exhibit Allen's Rule. The geographic variation is presumably adaptive and has developed within 138 years in the presence of a large, mobile beekeeping industry. Colonies of small worker bees in the warmer and drier regions of the state may represent an ecotype adapted to desert conditions.

2054. Dunlap, Kent D., and Jos. J. Schall. 1995. **Hormonal alterations and reproductive inhibition in male fence lizards (*Sceloporus occidentalis*) infected with the malarial parasite *Plasmodium mexicanum*.** Physiol. Zool. 68(4):608-621.
Abstract: When naturally infected with the malarial parasite *Plasmodium mexicanum*, western fence lizards, *Sceloporus occidentalis*, exhibit numerous reproductive pathologies. Infected males display fewer courtship and territorial behaviors, have altered sexually dimorphic coloration, and have smaller testes. Infected animals store less fat by late summer, which, for females, reduces clutch size in the spring. We describe hormonal alterations associated with malarial parasitism that may underlie this reproductive inhibition. We caught lizards in the field and bled them either immediately or 1 h after capture for measurement of basal and stress levels of steroid hormones. Compared to uninfected lizards, infected lizards had lower levels of basal plasma testosterone (24 vs. 38 ng/mL) and higher levels of corticosterone (18 vs. 8 ng/mL) following 1 h of capture and confinement. Infected animals also had lower levels of plasma glucose (243 vs. 270 mg/dL). When we experimentally elevated plasma corticosterone of uninfected lizards in large outdoor enclosures, the animals showed decreases in testosterone, testis size, and stored fat similar to those of infected animals in the wild. We hypothesize that the parasite induces alterations in the adrenal response to acute stress, resulting in a suppression of testosterone and the inhibition of reproductive behavior.

2055. Editor, California Agriculture. 1996. **Progress Report: Researchers stick it to ticks to curb Lyme disease.** Calif. Agric. 50(4):4-5.
Abstract: Lyme disease is a growing concern, particularly in northern California, with the highest reported incidence in Mendocino and Trinity Counties. The life cycle of the causative bacterial organism is summarized, as is the biology of the vector, the western black-legged tick. Current research led by Dr. Robert Lane of UC Berkeley has involved controlling ticks and fleas on woodrats, one of the disease's reservoirs, by means of insecticide-treated bait tubes. Investigations are also in progress to learn why western fence lizards do not become infected with Lyme disease when fed on by infected ticks.


David Egerter

An emergence trap placed over a water-filled treehole to sample emerging adults of the western treehole mosquito, Spring 1981

2056. Egerter, David E., and John R. Anderson. 1985. **Infection of the western treehole mosquito, *Aedes sierrensis* (Diptera: Culicidae), with *Lambornella clarki* (Ciliophora: Tetrahymenidae).** J. Invert. Pathol. 46:296-304.
Abstract: *Lambornella clarki* was a common parasite of *Aedes sierrensis* immatures collected from treeholes in Mendocino County, California, in 1982-83. The ciliate was not found in mosquitoes from treeholes with water having the most extreme values of electrical conductivity (<0.23 and >1.74 mmhos/cm) and pH (<6.5 and >7.7). Infection rates for individual monthly samples from *L. clarki*-positive treeholes ranged from 1% to 75%; 67% of all infections were observed in 4th-instar larvae. Infection with pathogens and parasites such as *L. clarki, Ascogregarina clarki, Octomyomermis troglodytis*, and unidentified bacteria and fungi, appeared responsible for high mortality rates (21% to 76%). Parasitism with *L. clarki* did not always result in death of the mosquito host; 7% of adults emerging from samples held in the laboratory were found to be infected. Ciliates were restricted to the hemocoel except in older females where they invaded the ovaries, resulting in parasitic castration. This phenomenon may be associated with parasitic dispersal.

2057. Egerter, David E., John R. Anderson, and Jan O. Washburn. 1986. **Dispersal of the parasitic ciliate *Lambornella clarki*: implications for ciliates in the biological control of mosquitoes.** Proc. Natl. Acad. Sci. 83:7335-7339.
Abstract: *Lambornella clarki* (Ciliophora: Tetrahymenidae) an endoparasite of *Aedes sierrensis* (Diptera: Culicidae) is dispersed by infected adult mosquitoes. Invasion of the ovaries induces parasitically castrated females to exhibit oviposition behavior and thereby actively disperse ciliates through deposition into water. Oviposition behavior of infected females is prolonged and mimics that of normal gravid females in their first gonotrophic cycle. Adults of both sexes also passively disperse ciliates by dying on water surfaces, and infected adults are more likely to die on water than uninfected adults. Ciliates dispersed by infected adults can infect larvae and form desiccation-resistant cysts. Parasite-induced dispersal by hosts, desiccation-resistant cysts, an active host seeking infective stage, and high infection and mortality rates all indicate significant biological control potential for these and related ciliates against container-breeding mosquitoes.

2058. Egerter, David E., and John R. Anderson. 1989. **Blood-feeding drive inhibition of *Aedes sierrensis* (Diptera: Culicidae) induced by the parasite *Lambornella clarki* (Ciliophora: Tetrahymenidae).** J. Med. Entomol. 26(1):46-54.
***Abstract*:** Female *Aedes sierrensis* infected with the parasitic ciliate

Lambornella clarki were significantly less responsive toward a human host than uninfected females. The proportion of infected females that were inhibited in host-seeking and blood-feeding remained high in all daily exposures to the host. Those that did not respond took approximately twice as long to land on the host and 25% longer to complete probing as did uninfected females. In contrast, nearly all uninfected females more than 5 days old rapidly responded to and blood fed on the host. For females allowed to ingest blood, the time from completion of probing to engorgement was not significantly different for infected versus uninfected females. Parasite-induced inhibition of the blood-feeding drive may explain low capture rates of *L. clarki*-infected mosquitoes at human bait

2059. Eisen, Rebecca J., and Jos. J. Schall. 1997. **Comparing foraging success in submissive malaria-infected and territorial noninfected fence lizards (*Sceloporus occidentalis*).** J. Herpetology 31(1):147-149.
Abstract: The western fence lizard, *Sceloporus occidentalis*, is often infected with a malaria parasite, *Plasmodium mexicanum*, at a site in northern California. Infected male lizards are not able to maintain a territory and are excluded from normal activity by more aggressive noninfected males. We used a measure of foraging success that did not harm the lizards (the mass of feces produced in 24 hours), and found that there was no difference in foraging success of infected and noninfected males. Therefore, the nonterritorial males had equal success in obtaining food as territorial males suggesting that territories in this population are not maintained to have access to food, but rather to court females.

2060. Eisen, Rebecca J. 2000. **Variation in life-history traits of *Plasmodium mexicanum*, a malaria parasite infecting western fence lizards: a longitudinal study.** Can. J. Zool. 78:1230-1237.
Abstract: The life history of malaria parasites (*Plasmodium* spp.) is directly related to their transmission, virulence, and population dynamics. I followed the life history of *P. mexicanum* in naturally infected western fence lizards (*Sceloporus occidentalis*) over a 4-year period, using a mark-recapture technique. The life-history traits measured included peak parasitemias and population growth rates of asexual forms, gametocytes, and total parasites. Among malaria infections, average asexual parasitemias ranged from 0.2 to 13.2 and gametocytemias from 0.5 to 66.2 parasites per 1000 erythrocytes. This variation was not related to infection prevalences, which were similar among years and between male and female hosts. Host age and gender were not related to peak parasitemia or average growth rate of asexual forms. However, the growth rate of gametocytes was higher in older lizards. Gametocytemia and parasitemia were significantly higher late in the warm season, when sandfly vectors are active. These data reveal that life-history traits of *P. mexicanum* are highly variable within an infected host population, and that the variation is partially related to the age of the infected host or the time of year the host was examined.

2061. Eisen, Rebecca J., and Dale F. DeNardo. 2000. **Life history of a malaria parasite (*Plasmodium mexicanum*) in its host, the western fence lizard (*Sceloporus occidentalis*): host testosterone as a source of seasonal and among-host variation?** J. Parasitol. 86(5):1041-1045.
Abstract: The course of infection of a malaria parasite (*Plasmodium mexicanum*) is highly variable in its host, the fence lizard (*Sceloporus occidentalis*). However, a seasonal trend is superimposed on this variation such that gametocyte production is intensified during mid- to late summer. Host testosterone levels follow a similar seasonal fluctuation and are variable among individual lizards. We sought to determine if testosterone levels affect seasonal and among-host variation in 11 *P. mexicanum* life history traits: rate of increase in level of infection (3 measures), peak parasitemia (3 measures), duration of increase (3 measures), time to detectable infection, and timing of production of gametocytes. We followed the course of infection in 125 male *S. occidentalis*, each randomly assigned to 1 of 4 treatment groups: castrated, castrated and implanted with exogenous testosterone, sham implanted, and unmanipulated controls. Median values for the 11 life history traits did not differ among treatment groups, and variances were homogeneous among the treatment groups for 10/11 traits. However, elevated testosterone significantly reduced the variation in timing of the onset of gametocyte production. Therefore, testosterone does not appear to be a primary regulator of *P. mexicanum* life history, yet testosterone may have some effect on when gametocytes first become detectable.

2062. Eisen, Rebecca J., and Jos. J. Schall. 2000. **Life history of a malaria parasite (*Plasmodium mexicanum*): independent traits and basis for variation.** Proc. R. Soc. Lond. 267:793-799.
Abstract: *Plasmodium mexicanum*, a malaria parasite of lizards, exhibits substantial variation among infections in the life-history traits which define its blood-dwelling stages. Such variation in life histories among infections is common in *Plasmodium* and may influence the ecology and evolution of the parasite's transmission success and virulence. Insight into these issues requires identification of independent traits (some traits may be bound by developmental trade-offs) and the importance of genetic versus host effects producing the variation. We studied 11 life-history traits in 120 induced infections of *P. mexicanum* in its natural lizard host (20 each from 6 donor infections). The traits varied among infections and fell into 3 clusters: rate/peak (rate of increase and peak parasitemia of asexuals and gametocytes), time (duration of pre-patent period and the infection's growth), and maturity (timing of the first gametocytes). Thus, few life-history traits define an infection in the lizard's blood. Donor effects were significant for 10 traits and 2 trait clusters (maturity was the exception) suggesting genetic differences among infections may influence the rate of increase and peak parasitemia, but not the timing of the first production of gametocytes.

2063. Eisen, Rebecca J. 2001. **Absence of measurable malaria-induced mortality in western fence lizards (*Sceloporus occidentalis*) in nature: a 4-year study of annual and over-winter mortality.** Oecologia 127:586-589.
Abstract: Theoretical models of parasite virulence often quantify virulence by mortality. However, there is a lack of empirical studies of parasite-induced host mortality because it is often difficult to quantify in natural populations. I have estimated annual and over-winter mortality in a population of fence lizards (*Sceloporus occidentalis*) infected with a malaria parasite, *Plasmodium mexicanum*, in northern California. The duration of time a lizard was observed (an estimate of life-span) throughout the 4-year observation period, or following winter, was not related to either infection status or maximum parasitemia. In contrast to previous laboratory studies of this parasite-host system, I found no evidence of parasite-induced host mortality in nature.

2064. Eisen, Rebecca J., Lars Eisen, and Robert S. Lane. 2001. **Prevalence and abundance of *Ixodes pacificus* immatures (Acari: Ixodidae) infesting western fence lizards (*Sceloporus occidentalis*) in northern California: temporal trends and environmental correlates.** J. Parasitol. 87(6):1301-1307.
Abstract: The prevalence and abundance of immature *Ixodes pacificus* ticks on western fence lizards (*Sceloporus occidentalis*) were examined in relation to time of year, host attributes (i.e., age, gender, and presence or absence of blood parasites), and 5 environmental characteristics, including topographic exposure and ground cover substrate, over a 2-year period at Hopland. Lizards were infested with subadult ticks from early March until late July or early August, with peak median numbers of larvae and nymphs recorded in late April and early May of both years. Peak larval and nymphal abundances differed between years. The overall ratio of

larvae to nymphs on adult male lizards was low, ranging from 0.80 in 1999 to 2.41 in 2000. Such intensive feeding of nymphs versus larvae on these lizards, which are reservoir-incompetent for *Borrelia burgdorferi* spirochetes, may explain previous observations of decreasing spirochetal infection prevalence from the nymphal to adult stage in northwestern California. Adult male lizards were more likely to be infested with nymphs and harbored greater abundances of larvae and nymphs than adult females. Lizards uninfected with blood parasites had more nymphs than infected lizards. The measured environmental characteristics could explain only a small percentage of the total variation observed in larval prevalence (22%) and in larval and nymphal abundance (12% and 3%, respectively).

2065. Eisen, Rebecca J., and N. M. Wright. 2001. **Landscape features associated with infection by a malaria parasite (*Plasmodium mexicanum*) and the importance of multiple scale studies.** Parasitol. 122:507-513.
Abstract: In a 3-year study, we examined landscape features (aspect, slope, sun exposure, canopy cover, type of ground cover, and nearest water source) that were potentially related to prevalence of infection with *Plasmodium mexicanum* in fence lizards (*Sceloporus occidentalis*) within a 4.5 ha study area at Hopland. Logistic regression analysis showed that ground cover type was the primary mediator of the probability of *P. mexicanum* infection. Infected lizards were captured more often in rock and/or leaf litter locations than in grassy ones. In another experiment, the study area was divided into 9 sites (0.07–0.33 ha), and infection prevalence was calculated for each. Three sites with high (>30%) infection prevalence ($N = 3$ sites each). We conclude that lizard site selection may influence the probability of exposure to infected vectors and thus the likelihood of *P. mexicanum* infection. We also demonstrate that studies at different spatial scales may be required to understand fully the relationship between landscape features and parasite distribution.

2066. Eisenberg, Joseph N. S., Jan O. Washburn, and Sebastian J. Schreiber. 2000. **Generalist feeding behaviors of *Aedes sierrensis* larvae and their effects on protozoan populations.** Ecology 81(4):921-935.
Abstract: The generalist feeding strategy of larvae of the western tree hole mosquito, *Aedes sierrensis*, is central to understanding the community-level effects of the tritrophic interactions among mosquito larvae, midsized organisms (such as protozoa), and lower-level organisms (such as bacteria and fungi) in west coast phytotelmata. Laboratory microcosm experiments were conducted to characterize the feeding strategies of *Ae. sierrensis* larvae in the presence of multiple resource types (free-swimming protozoa and substrate-bound particulate matter). In our experiment, we quantified the effects of varying instar numbers and profile, resource type, and refuge size on predation of protozoa. Refugia were explicitly modeled in our microcosms, representing the interstitial spaces of leaf letter and the wood lining of natural tree holes. Results from these microcosm experiments suggested that: 1) Even in the absence of larvae, the majority of protozoa resided in the small-volume, resource-rich refugia. There was, however, a strong nonlinear and negative relationship between larval densities in the upper compartment and the protozoan densities in the refuge, suggesting that there was continual movement of protozoa between the two spaces. 2) Fourth instars harvested resources by filter-feeding at a higher rate than second instars. 3) As the level of substrate-bound particulate food was increased, the predation pressure by filter-feeding on the protozoa decreased. 4) As the refuge volume increased, the predation pressure on the protozoa decreased. We constructed a three-state-variable mathematical model describing the generalist feeding behavior of *Ae. sierrensis* larvae. The model system, with constant predator densities and two prey groups, exhibited full cooperativity; i.e., an increase in protozoa density resulted in a shift toward predation by filter feeding, while an increase in substrate-bound resources resulted in a shift toward predation by browsing. This indirect mutualism is mechanistically distinct from previously published systems and provides a potential mechanism for protozoan persistence in the presence of larval predation.


Guy E. Connolly

Val Dutson, state public health biologist, bleeds newborn lamb to check Q-fever incidence, Main Barn, January 1965

2067. Enright, John B., William M. Longhurst, Charles E. Franti, Michael E. Wright, Val J. Dutson, and Darrell E. Behymer. 1969. **Some observations on domestic sheep and wildlife relationships in Q-fever.** Proc. Ann. Conf. Bull. Wildl. Dis. Assoc. 5:276-283.
Abstract: A cycle of prevalence of Q-fever antibodies in sheep is confirmed, and possible relationships between sheep, wild mammals, and birds in the ecology of Q-fever are exhibited. Carnivores and carrion-eaters, including coyotes (*Canis latrans*) turkey vultures (*Cathartes aura*), grey foxes (*Urocyon cinereoargenteus*), and hawks (red tailed hawk, *Buteo jamaicensis* and sparrow hawk, *Falco sparverius*) have serological evidence of Q-fever indicating exposure relative to their food habits. Herbivorous mammals and birds have evidence of Q-fever exposure relative to their relationship with sheep: species that share the same pastures as the sheep have higher percentage with Q-fever antibodies than species inhabiting the protective underbrush or species that are more independent of the activities of livestock. A detailed study of 5 representative wildlife species, including the deer mouse (*Peromyscus maniculatus*), black tailed jackrabbit (*Lepus californicus*), Columbian black-tailed deer (*Odocoileus hemionus columbianus*), ground squirrel (*Citellus beecheyi*) and the common red-winged blackbird (*Agelaius phoeniceus*) indicated that the blackbird has a peak prevalence of antibodies before that of sheep, the black-tailed jackrabbit and the ground squirrel seem to parallel sheep in cyclic responses, and the peak prevalence of Q-fever antibodies in the deer mouse occurs after the peak responses in sheep. Deer responses appear to be unrelated to sheep responses.

2068. Enright, John B., Charles E. Franti, William M. Longhurst, Darrell E. Behymer, Michael E. Wright, and Val J. Dutson. 1971. ***Coxiella burnetii* in a wildlife-livestock environment: antibody response of ewes and lambs in an endemic Q fever area.** Am. J. Epidemiol. 94(1):62-71.
Abstract: Two independent cycles of Q fever have been hypothesized: one in wildlife, and the other in domestic livestock. We investigated the prevalence of Q fever antibodies in livestock and wildlife sharing the same habitat to determine the ecology of *Coxiella*

burnetii under the influence of these two cycles. A serological study of ewes and lambs during a 2-year period indicated a recurring annual cycle of Q fever in sheep. Seasonal changes in the prevalence of Phase II complement-fixing (CF) antibodies to *C. burnetii* in sheep are believed to reflect their exposure to the rickettsiae. The peak prevalence of CF antibodies in ewes (55%) was in March, 8 to 12 weeks following the December-February lambing period. This peak may be in response to exposure to *C. burnetii* shed during parturition. The prevalence of CF antibodies in ewes was lowest in late September (18%). Lambs born in two consecutive years were tested at birth and on selected dates through their first year of life. The levels of detectable Q fever CF antibodies were similar in these two populations: from 7% to 18% of the lambs were antibody positive on the day of birth and the prevalence of CF antibodies in lambs slowly increased through the summer to a peak of approximately 30% in September. The level of antibodies in these cohorts declined through the fall but reflected an increase in the prevalence of detectable antibodies during the respective succeeding lambing periods. By the end of the first year the prevalence of Phase II CF antibodies to *C. burnetii* in lambs was similar to that in adult sheep population. The major source of infection in the sheep population appears to be *C. burnetii* shed in the placentas of infected ewes during the lambing season. There was no evidence that the prevalence of Q fever in these sheep was influenced by wildlife.

2069. Enright, John B., William M. Longhurst, Charles E. Franti, Darrell E. Behymer, Val J. Dutson, and Michael E. Wright. 1971. ***Coxiella burnetii* in a wildlife-livestock environment: isolations of rickettsiae from sheep and cattle.** Am. J. Epidemiol. 94(1):72-78.
Abstract: *Coxiella burnetii* was studied in sheep and cattle during parturition as part of an ecological investigation of Q fever in an area shared by livestock and wildlife. The rickettsiae were isolated from 13 of 52 (25%) placentas from resident ewes and the milk of 2 postpartum cows. A herd of nonresident cattle was pastured on the sheep range for 6 months, during which time the proportion of the herd with specific antibodies increased from 5% to 71%. The comparatively low antibody titer in sheep and the low virulence of the strains of *C. burnetii* isolated from ewes indicated a possible adjustment in the host-parasite relationship through prolonged sheep-to-sheep transmission.

2070. Enright, John B., Charles E. Franti, Darrell E. Behymer, William M. Longhurst, Val J. Dutson, and Michael E. Wright. 1971. ***Coxiella burnetii* in a wildlife-livestock environment: distribution of Q fever in wild mammals.** Am. J. Epidemiol. 94(1):79-90.
Abstract: Q fever was studied in the wild mammal fauna of the area on and around the Hopland Field Station. Based on detectable phase II complement-fixing serum antibodies, there was evidence of exposure to *Coxiella burnetii* in 17 of 21 species tested. The highest prevalence was in coyotes (78%), foxes (55%) and brush rabbits (53%). The lowest was in gray squirrels (6%), woodrats (3%) and kangaroo rats (2%). Deer had a prevalence of 22%, and the prevalence of antibody in wild mice (*Peromyscus*) ranged from 31% in brush mice to 9% in piñon mice. Other animal species having antibodies were harvest mice, deer mice, meadow mice, jackrabbits, chipmunks, ground squirrels, raccoons and striped skunks. No Phase II complement-fixing antibodies to *C. burnetii* were detected in the bobcats and feral cats that were tested. *C. burnetii* was isolated from 9 of 20 wild mammal species tested and 2 kinds of ticks. The prevalence of detectable antibodies in wildlife appeared to be related to their association with infected livestock or small mammals. Exposure and possible infection through the respiratory route may have been related to the food habits of wild animals. The kinds of animals that feed on the same pastures as infected livestock had a higher prevalence than those from bordering areas. Certain carnivores may have become exposed to *C. burnetii* while eating infected sheep or wild animals.

2071. Enright, John B., William M. Longhurst, Michael E. Wright, Val J. Dutson, Charles E. Franti, and Darrell E. Behymer. 1971. **Q-fever antibodies in birds.** J. Wildl. Dis. 7:14-21.
***Abstract*:** Serum samples were obtained from 307 birds collected in a sheep range (Hopland Field Station) in northern California. Forty (13%) of these birds had agglutinating antibodies to *Coxiella burnetii.* At a nearby dairy farm, sera from 49 of 129 (38%) birds tested were positive for Q-fever antibodies. In both areas the birds with the highest antibody prevalence were the carrion-eating birds (crows, ravens, and turkey vultures) and those birds (Brewer's and red-winged blackbirds, golden-crowned sparrows, and pigeons) that live and feed in close proximity to infected livestock. The extent to which migratory birds are involved in the ecology of this zoonosis is uncertain. Immigrant birds may have been exposed to Q-fever prior to their arrival in the area; however, emigrating birds have the potential to disperse the rickettsiae from such areas where livestock are infected with *C. burnetii.*

2072. Enright, John B., Darrell E. Behymer, Charles E. Franti, Val J. Dutson, William M. Longhurst, Michael E. Wright, and J. E. Goggin. 1971. **The behavior of Q fever rickettsiae isolated from wild animals in Northern California.** J. Wildl. Dis. 7:83-90.
Abstract: The biological properties of strains of *Coxiella burnetii* from 9 species of wild animals and 2 species of ticks, collected at Hopland, were compared to the properties reported for the highly infectious wildlife strains isolated from rodents in Utah. The Hopland strains are thought to be similar to the Utah strains because they were usually more infectious for hamsters and induced higher antibody responses in this host than in guinea pigs or mice. The Hopland strains did not cause a febrile response and were difficult to transfer in guinea pigs. Although a slight splenomegaly was evident in inoculated mice and hamsters, there was no exudate around the spleen nor granuloma at the site of injections, as induced by typical virulent strains in *C. burnetii.* The Q fever rickettsiae isolated from deer and coyotes were the most infectious of the Hopland strain. They induced higher antibody responses in guinea pigs during the primary isolation and were more easily transferred through laboratory hosts. Both the Utah and Hopland wildlife strains were isolated from animals collected in areas where livestock were present. It is not known whether the infectivity of certain strains of *C. burnetii* is influenced by host parasite equilibrium in an animal population chronically exposed to the organism.

2073. Fialho, Roberto F., and Jos. J. Schall. 1995. **Thermal ecology of a malarial parasite and its insect vector: consequences for the parasite's transmission success.** J. Anim. Ecol. 64(5):553-562.
Abstract: We examined the transmission biology of *Plasmodium mexicanum*, a parasite of the fence lizard *Sceloporus occidentalis*, and its vector, the sandfly *Lutzomyia vexator*. Female *L. vexator* produced a clutch of eggs after each blood meal taken from a lizard. Mortality was high after oviposition, so few sandflies were likely to take 2 blood meals and almost none took 3. Therefore, to maximize its transmission success, the parasite must complete development in its insect host before the vector lays its eggs and takes another blood meal. Between 16° and 32°C temperature did not affect the longevity of female sandflies, but it did affect the rate of parasite development in the insect, the rate of maturation of sandflies' eggs, and the probability of sandflies becoming infected. The above relationships with temperature were non-linear and differed in shape among the variables such that an increase in temperature between 22°C and 32°C benefited the parasite by shortening its development while not reducing the time until the sandfly's next blood meal. We measured the temperatures available to the vectors in nature (burrows of ground squirrels, *Spermophilus beechyi*). Within this range, there was a window that allowed successful transmission of the parasite (based on laboratory studies). In a thermal gradient, unfed female

sandflies selected mean temperatures approximately 4°C below the minimum required for transmission. After a blood meal from a non-infected lizard, the insect's mean preferred temperature increased 1.6°C, presumably to aid digestion, and if a blood meal was taken from an infected lizard mean preferred body temperature increased by 3.6°C. Compared with 10 other *Plasmodium* species, *P. mexicanum* has a very rapid rate of development in its vector. The results suggest *P. mexicanum* enhances its transmission success through a combination of rapid development in the insect host and manipulation of the vector's thermoregulatory behavior.

2074. Franti, Charles E., Guy E. Connolly, H. P. Reimann, Darrell E. Behymer, R. Ruppanner, C. M. Willadsen, and William M. Longhurst. 1975. **A survey for *Toxoplasma gondii* antibodies in deer and other wildlife on a sheep range.** J. Am. Vet. Med. Assoc. 167(7):565-568.
Abstract: Blood samples were obtained from native mammals and birds on a sheep range (Hopland Field Station) in northern California. Sera were tested for antibodies to *Toxoplasma gondii* by the indirect hemagglutination test. Of 382 deer that were tested form 1964 to 1973, 77 (20%) were seropositive for *T. gondii*. Among 36 sera representing 6 species of wild carnivores (badgers, bobcats, coyotes, foxes, raccoons, and skunks), 18 (50%) were positive. All of the five bobcats tested were seropositive, with antibody titers ranging from 1:1,024 to 1:65,536. The testing of 175 sera from small wild mammals indicated antibody prevalence of 8% among jackrabbits, 6% among brush rabbits, and 2% among gray squirrels and ground squirrels. None of the native mice tested was seropositive for *T. gondii.* Of 120 native birds tested, 6 (5%) were seropositive. Of the resident domestic species of animals tested, antibodies were found in 1 of 7 domestic cats, 1 of 5 feral cats, 1 of 2 dogs, and 54 (13%) of 405 sheep.

2075. Gambino, P., K. Hoelmer, and H. V. Daly. 1990. **Nest sites of feral honey bees in California, USA.** Apidologie 21:35-45.
Abstract: Nest site characteristics are described for 94 honey bee nests in trees, 17 in the ground, and 82 in man-made structures. Nests were in trees of mean diameter 85 cm primarily in live hardwoods, especially oaks. Entrances were mostly single knots or cracks in the main trunk at ground level and up to a mean height of 2.5 m. Most nests in the ground were in treeless areas; half had partially exposed combs, possibly aiding ventilation. Nests in buildings differed from those in trees by having smaller entrances. Compass orientation of comb in natural nest sites was commonly from 145 to 195°.

2076. Hendson, Mavis, and Robert S. Lane. 2000. **Genetic characteristics of *Borrelia coriaceae* isolates from the soft tick *Ornithodoros coriaceus* (Acari: Argasidae).** J. Clin. Microbiol. 38(7):2678-2682.
Abstract: Two *Borrelia* isolates (CA434 and CA435) cultured from the soft tick *Ornithodoros coriaceus* were analyzed by contour-clamped homogeneous electric field gel electrophoresis of unrestricted and *Apa*I-restricted DNA, standard electrophoresis of *Bam*HI- and *Hind*III-restricted DNA, Southern hybridization, restriction fragment length polymorphism and sequencing of the 16S rRNA gene, and amplification of the 5S-23S intergenic spacer region. These isolates were compared with *Borrelia coriaceae* type strain Co53, *B. burgdorferi* sensu stricto strain CA4, and the relapsing-fever spirochete *B. parkeri* (undesignated). The 16S rRNA region of CA434 and CA435 differed from that of *B. coriaceae* type strain Co53 by the presence of 1 base (C) at position 367 (GenBank accession no. U42286). The linear plasmid profile of CA434 was similar to that of Co53, and the *Apa*I, *Bam*HI, and *Hind*III restriction fingerprints of the total cellular DNA of CA434 and Co53 were similar. In contrast, CA435 differed somewhat from CA434 and Co53, which demonstrates that *B. coriaceae* is genetically diverse. Southern hybridization showed that the DNAs of CA434 and CA435 hybridized strongly with the digoxigenin-labeled DNA of Co53. Low homology was found between the DNA of Co53 and that of *B. parkeri*. The 16S rRNA sequence of *B. parkeri* was identical to previously published results for *B. parkeri* strain M3001 (GenBank accession number U42296). CA434 and CA435 represent only the second and third isolates of *B. coriaceae* obtained from any source since its initial isolation from an *O. coriaceus* tick in 1985. All three *B. coriaceae* isolates were derived from adult ticks collected from the same locality in northwestern California. Difficulties encountered in detecting *B. coriaceae* in, and isolating this spirochete from, the tissues of *O. coriaceus* are discussed. The lack of concordance between different detection or isolation methods suggests that reliance upon a single technique may grossly underestimate the true prevalence of spirochetal infection in wild-caught *O. coriaceus* ticks.

2077. Hokama, Yoshiaki, and J. A. Howarth. 1977. **Dry-ice (CO_2) trap for efficient field collection of *Ornithodoros coriaceus* (Acarina: Argasidae).** J. Med. Entomol. 13(4-5):627-628.
Abstract: This publication describes the materials and construction of a trap for collecting ground-living ticks of the species *Ornithodoros coriaceus.* The collection of nearly 4,000 *O. coriaceus* ticks from the Hopland Field Station indicates that an effective and economical CO_2 tick trap has been developed. Readily available items, such as plastic freezer containers and an enamel pan, are used in construction. The components are inexpensive and lightweight for transport without motor vehicles. One person easily carried and attended 12 traps which were usually placed for overnight collections. Ticks contained in the traps were viable, dry, and not frozen, because there was no opportunity for direct contact with the dry ice. Considerable numbers of larvae were obtained with the traps, while none was collected by the continual-surveillance hand-pick-up method.

2078. Howarth, J. A., T. O. Roby, T. E. Amerault, and D. W. McNeal. 1969. **Prevalence of *Anaplasma marginale* infection in California deer as measured by calf inoculation and serologic techniques.** Pp. 136-147 *in:* Proc. 73rd Ann. Mtng. U.S. Anim. Health Assoc.
Abstract: This study was conducted to provide additional information on the prevalence of *Anaplasma* infection in California black-tailed deer. Individual deer blood samples, taken from study sites at the Hopland Field Station and at a private ranch 5 miles from the Station, were inoculated into individual test calves within 1 hour after collection. This provided an opportunity to compare the accuracy of the complement-fixation (CF), capillary tube agglutination (CA), and card agglutinations tests on sera of infected and non-infected deer. Three calves developed antibody levels detectable on all 3 serological tests, but *Anaplasma* bodies could not be demonstrated in blood smears. A splenectomomy was performed on the third calf and *Anaplasma* bodies were detected 12 days later to confirm the infection. When the prevalence of infection was compared with the age of deer, infection was closely associated with increased age. In fawns less than 1 year of age, infection incidence was 31%; in yearling deer, 47%, and in adult deer aged 2 or older, 92%. These results suggest that *Anaplasma* infection in black-tailed deer is accumulative and that, once infected, an animal likely remains a carrier the rest of its life. Although sample size was small, it did not appear that deer in close association with cattle had a higher infection incidence than non-cattle associated deer. Each of the 3 tests, and particularly the CF test, was plagued by false negative reactions, especially in young fawns and in adult deer with long-standing infections. Best results were obtained with samples from yearling deer where the CA test had an overall accuracy of 94%.

2079. Howarth, J. A., T. O. Roby, and D. Stiller. 1972. **Apparent failure of *Ornithodoros coriaceus* Koch (Acarina: Argasidae) to**

transmit anaplasmosis to cattle. Pp. 94-97 *in:* Proc. 76th Ann. Mtg. U.S. Anim. Health Assoc.
Abstract: No evidence of *Anaplasma marginale* infection was detected in 3 splenectomized calves which served as a blood meal source for nymphal and adult stages of *Ornithodoros coriaceus*. These ticks had been collected in an area where anaplasmosis was enzootic in the deer population. Ticks of the same species which obtained a blood meal from an infected calf in the laboratory did not transmit the infection to 2 splenectomized calves on a subsequent feeding.

2080. Howarth, J. A., and T. O. Roby. 1972. **Transmission of anaplasmosis by field collections of *Dermacentor occidentalis* Marx (Acarina: Ixodidae).** Pp. 98-102 *in:* Proc. 76th Ann. Mtng. U.S. Anim. Health Assoc.
Abstract: Adult *Dermacentor occidentalis* ticks were collected from vegetation by the flagging technique in an anaplasmosis enzootic area inhabited only by deer and smaller wildlife species. *Anaplasma marginale* infection was not produced when 64 male, 66 female, and a combination of 44 male and 56 female ticks were allowed to attach and feed on susceptible splenectomized calves. Anaplasmosis was produced however, when 435 apparently unfed adult ticks of both sexes were used to infest an intact cow. These results indicate that transmission of anaplasmosis from the deer reservoir to cattle by *Dermacentor occidentalis* ticks does occur.

2081. Howarth, J. A., and Y. Hokama. 1973. **Tick transmission of anaplasmosis under laboratory conditions.** Pp. 117-120 *in:* Proc. 6th Nat. Anaplasmosis Conf., Las Vegas, NV, Mar. 19-20.
Abstract: Several tick species indigenous to the anaplasmosis enzootic area of the western United States were used in a series of controlled laboratory trials to more clearly define their vector potential. Various instars of *Ixodes pacificus*, *Dermacentor occidentalis*, and *D. andersoni* were allowed to engorge on splenectomized calves during the period of maximum parasitemia following infection with *Anaplasma marginale*. Transstadial transmission was not obtained with *I. pacificus* in a single nymph to adult trial. Nymph to adult transstadial transmission of single anaplasmosis by *D. occidentalis* was produced, but adults fed on the same donor calf did not pass the parasite to succeeding instars. An anaplasmosis transmission procedure using parenteral injection of macerated prefed adult ticks was developed. Transmission was not obtained by parenteral injection of a calf with saliva collected from prefed adult *D. andersoni* ticks.

2082. Howarth, J. A., and D. W. McNeal. 1973. **The occurrence of bovine anaplasmosis following controlled natural exposure.** Pp. 123-126 *in:* Proc. 6th Nat. Anaplasmosis Conf., Las Vegas, NV, Mar. 19-20.
Abstract: *Anaplasma marginale*-susceptible cattle were subjected to conditions of natural exposure in an environment where other cattle were excluded as a source of anaplasma infection. The cattle were monitored once weekly during a 3-month exposure period and for an additional 3 months to determine the incidence and severity of *Anaplasma marginale* infection. Subclinical anaplasmosis, as judged by the results of complement fixation testing, occurred in 5 of 9 cows maintained under conventional spring pasture conditions. In a subsequent year, 5 of 6 cows maintained in the same manner became infected, while no infection occurred in 6 cows placed on a tick-proof platform in the same pasture. Thus, a persistent non-bovine reservoir of *A. marginale* infection exists in California in deer, and arthropod transmission of this infection to cattle occurs readily. Ticks are most likely to be the only natural vectors in the area capable of maintaining exposure to *Anaplasma* infection at the high levels demonstrated. These trials confirmed the common belief that both anaplasmosis and abortion are likely to occur when susceptible cattle are grazed in the Coast Range brushlands of California. Interpretation would indicate that the cows free to graze the pasture in these trials were exposed to 2 disease-causing agents. In each trial, a cow which did not become infected with *A. marginale* aborted, while a total of 3 cows did become infected without abortion resulting. In addition, the near-term aborted fetuses did not contain complement-fixing antibodies for anaplasmosis. It can therefore be stated that *A. marginale* infection which does not produce demonstrable clinical signs is not a significant cause of bovine abortion. The probable reservoirs and vectors of anaplasmosis within this enzootic area are discussed.


Guy E. Connolly
Jack Howarth's tick-proof cattle pen, Orchard Pasture, Summer 1971

2083. Howarth, J. A., Y. Hokama, and T. E. Amerault. 1976. **The modified card agglutination test: an accurate tool for detecting anaplasmosis in Columbian black-tailed deer.** J. Wildl. Dis. 12:427-434.
Abstract: Inoculation of susceptible calves confirmed that the modified card agglutination test accurately detected anaplasmosis infection in Columbian black-tailed deer (*Odocoileus hemionus columbianus*). *Anaplasma marginale*, and specific antibodies, were demonstrated only in calves which received blood from deer that were positive by the card test. The modified card agglutination testing of deer serum was performed in the manner recommended for testing cattle serum with bovine-origin antigen and bovine serum factor.

2084. Howarth, J. A., and Y. Hokama. 1978. **Studies with *Ornithodoros coriaceus* Koch (Acarina: Argasidae), the suspected vector of epizootic bovine abortion.** Pp. 168-176 *in:* J. K. H. Wilde (ed.), Tick-borne Diseases and Their Vectors. Univ. Edinburgh Press, Edinburgh, Scotland.
Abstract: Epizootic bovine abortion (EBA) was first reported as a separate disease entity in 1956 and was so named because the abortion was widespread in certain areas, and had both high incidence within a herd and seasonal incidence. The argasid tick *Ornithodoros coriaceus* is widely distributed in the coastal and mountainous regions of California and lives in the substrate under trees and brush which are the habitat of deer and cattle. When it was first suspected of being a vector of EBA, little was known about this species' geographic distribution, methods of collecting specimens, feeding habits, laboratory colonization, and its vector potential. In this study, it was found that all stages of *O. coriaceus* are attracted to CO_2 and can be collected in traps in considerable numbers. This tick readily feeds on experimental animals and can be maintained in the laboratory for extended periods. A device for routine artificial feeding of nymphal and adult *O. coriaceus* was developed. The 4 stimuli necessary for attachment to, and feeding through, an artificial membrane were: hair on the feeding surface; parafilm as a skin substitute; for the feeding surface and food to be maintained at 37-39°C; and food sources such as glutathione solution, cell-culture

medium foetal calf serum, or red blood cells. Using this system, ticks could be exposed to known amounts of a virus in a manner approximating natural exposure. Using an arborvirus, the nearly universal presence of the arborvirus was demonstrated in haemolymph and salivary glands for 7 days after ingestion of cell-cultured virus. Future studies should allow a more accurate assessment of the vector potential of *O. coriaceus*.

2085. Hoy, James B. 1966. **The behavior of members of the genus *Symphoromyia* attacking deer in northern California (Diptera: Rhagionidae).** Ph.D. Dissertation, Univ. Kansas. 162 pp.
Abstract: The purposes of this research was to determine the vector potential of those *Symphoromyia* attacking deer; to study the attack behavior of a primitive group of blood-sucking flies; to contribute information on the general biology of this genus; and to determine what biological and physical factors influence the attack rates. Conclusions include the following: The immature stages *Symphoromyia* are not easily studied at Hopland and offer little hope as a means of estimating the size of the *Symphoromyia* population. Five types (5 or 6 species) of *Symphoromyia* attack deer during April, May, and June. The various types display similar seasonal patterns of abundance of adult females in that each type is found over a period of 6 to 10 weeks without a conspicuous period of occurrence. Of the orthorrhaphous Diptera attacking deer at Hopland during spring, the genus *Symphoromia* is the most common and probably takes a greater total volume of blood than any other group. Parous *S. sackeni* begin to attack hosts approximately 10 days after nulliparous females begin making attacks. An individual female *S. sackeni* is part of the attacking population for approximately 25 days. As many as 3 or 4 gonadotrophic cycles may be completed by certain *S. sackeni* females. The attacking population reaches maximum numbers very near the midpoint of the *S. sackeni* season. The 5 types of *Symphoromyia* taken on deer are seldom attracted to hosts other than deer. *S. limata* females take blood-meals from man. All types of *Symphoromyia* studied attack only the face, ears, or antlers of deer after relatively direct approach. Most types engorge in 1 to 3 minutes after approach. *S. sackeni* females take approximately 5.5 mg of blood per blood-meal. The number of *Symphoromyia* attracted to different individual deer and to various sites on individual deer varies greatly, with the host's behavior appearing to influence numbers on and around individual hosts. Minimum and maximum temperature thresholds for *Symphoromyia* attack were determined; wind and light conditions have little apparent effect on attack. The behavior of *S. sackeni* and the *S. pachyceras* complex suggests real vector potential for disease of deer. Furthermore, *S. sackeni* may serve as a vector of zoonoses.

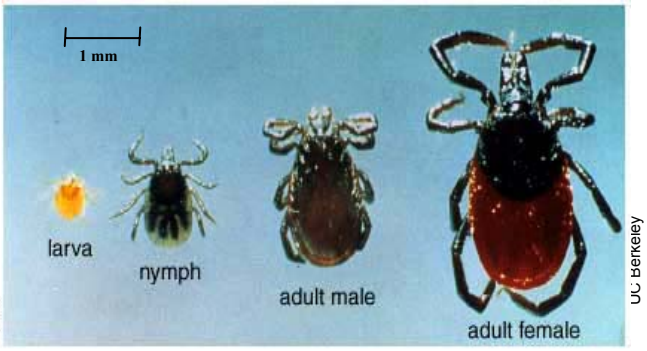
2086. Hoy, James B., and John R. Anderson. 1966. **Snipe flies (*Symphoromyia*) attacking man and other animals in California.** Pp. 61-64 *in:* Proc. Calif. Mosq. Control Assoc., Vol 34, Monterey, CA, Jan. 30 - Feb. 2.
Abstract: In many areas of the western United States and Canada, snipe flies (*Symphoromyia* spp.) are locally abundant during certain years, causing annoyance to man, livestock, and game animals. This paper summarizes current taxonomic and ecological knowledge about this group of blood-feeding insects. Within this genus, there are thought to be 6 species limited to the Coastal Range, 6 species limited to the Sierra Nevada, and 5 species shared by both ranges. We summarize and recount scientific and historical records of the various species and their tendency to attack humans. However, the potential medical and veterinary importance of these flies is not well determined. The increasing importance of the foothills and mountains as recreation areas undoubtedly will make these flies more noticed in future years.

2087. Hoy, James B., and John R. Anderson. 1978. **Behavior and reproductive physiology of blood-sucking snipe flies (Diptera: Rhagionidae: *Symphoromyia*) attacking deer in Northern California.** Hilgardia 46(4):113-168.
Abstract: At the Hopland Field Station, 6 species of hematophagous *Symphoromyia* attacked Columbian black-tailed deer, *Odocoileus hemionus columbianus*, during the months of transition (April through June) from the rainy season to the drought season. Between 1964 and 1966, *S. pachyceras*, *S. cervivora*, *S. inconspicua*, *S. nana*, *S. truncata*, and *S. sackeni* had similar seasonal patterns of abundance, with each present 6 to 10 weeks. Minimum temperature thresholds at which *Symphoromyia* attacked were determined for 5 species. The upper temperature threshold for attack by *S. sackeni* was between 34.4 and 37.2°C. Diverse wind and light conditions had little effect on the host-seeking behavior of the species studied. *Symphoromyia* attacking deer were seldom attracted to hosts other than deer, and only *S. sackeni* and *S. pachyceras* fed on other hosts. The seasonal occurrence of snipe flies coincided with the annual spring shedding of winter pelage by the deer, and in bucks, with the growth of antlers. All *Symphoromyia* attacked only the face, ears or antlers of deer, and most species engorged within 1 to 3 minutes. There was a direct relationship between snipe flies feeding on the ears and face and the more rapid loss of the wooly underhairs at these sites. The tilted posture of feeding snipe flies that angled the body upward between and above raised guard hairs permitted feeding on the outer ear surface, a site where most other blood-sucking flies are repulsed by the sensory guard hairs. The number of *Symphoromyia* attracted to an individual deer and to the face or ears of an animal varied greatly. The tolerance to flies and the anti-biting fly behavior of individual deer (ear-flicking, brushing flies from the face, and reducing the silhouette by lying down, lowering the head, flattening the ears, and extending the legs) contributed to the variations in numbers of snipe flies on and around the hosts. Mating swarms of *S. sackeni* males were active between about 1000 to 1600 hours. Both inseminated and non-inseminated, recently emerged nulliparous females, and pairs of males and females flying *in copulo*, were captured from these mating swarms. All nulliparous females attacking deer had been inseminated, and all species were anautogenous with gonotrophic concordance. Parous females were distinguished from nulliparous individuals by changes occurring in the ovarioles after oviposition. A study of the seasonal parity of *S. sackeni* revealed that: 1) parous females began to attack deer about 10 days later than did nulliparous females, 2) an individual female was part of the attacking population for about 25 days, and 3) as many as 3 or 4 gonotrophic cycles were completed by certain females. A model of *S. sackeni* adult population dynamics is presented.

2088. Johnson, Russell C., Willy Burgdorfer, Robert S. Lane, Alan G. Barbour, Stanley F. Hayes, and Fred W. Hyde. 1987. ***Borrelia coriaceae* sp. nov.: putative agent of epizootic bovine abortion.** Int. J. System. Bacteriol. 37:72-74.
Abstract: Genetic and phenotypic characteristics of the possible agent of epizootic bovine abortion, the *Ornithodoros coriaceus* spirochete, revealed that this organism is a new species of *Borrelia.* We propose the name *Borrelia coriaceae* for this species. The type strain of *B. coriaceae* is strain Co53 (= ATCC 43381). The guanine-plus-cytosine content of the deoxyribonucleic acid of the type strain was determined to be 32.4 mol% (thermal denaturation method).

2089. Kain, Douglas E., Felix A. H. Sperling, and Robert S. Lane. 1997. **Population genetic structure of *Ixodes pacificus* (Acari: Ixodidae) using allozymes.** J. Med. Entomol. 34(4):441-450.
Abstract: Genetic analysis of the population structure of the western blacklegged tick, *Ixodes pacificus*, was conducted using allozymes. This vector tick transmits the Lyme disease spirochete, *Borrelia burgdorferi*, in the far-western United States. It ranges from British Columbia to Baja California and disjunct populations are present in Oregon, Nevada, Utah, and Arizona. Host-seeking adult ticks were

collected from vegetation across the range of the species and were partially fed on rabbits prior to analysis. Twelve putative loci were resolved using starch gel electrophoresis. One locus, glucose-6-phosphate isomerase, formed an apparent north/south latitudinal cline and showed significant geographic structure. None of the remaining loci exhibited much genetic differentiation. Estimates of gene flow were high relative to other arthropods. Isolation-by-distance analysis suggests a recent and rapid range expansion. We conclude that the overall lack of differentiation is due high rates of gene flow.



Life stages of the western black-legged tick, *Ixodes pacificus*, the primary vector of the agent causing Lyme disease

2090. Keirans, James E., Richard N. Brown, and Robert S. Lane. 1996. ***Ixodes* (Ixodes) *jellisoni* and *I.* (I.) *neotomae* (Acari: Ixodidae): descriptions of the immature stages from California.** J. Med. Entomol. 33(3):319-327.
Abstract: Nymphal and larval stages of *Ixodes* (*I.*) *jellisoni* and *I.* (*I.*) *neotomae* are described for the first time. These 2 tick species occur only in the western U.S., predominantly in California. The primary host for *I. jellisoni* is the California kangaroo rat, *Dipodomys californicus*; that for *I. neotomae* is the dusky-footed woodrat, *Neotoma fuscipes*. The etiologic agent of Lyme disease *Borrelia burgdorferi* has recently been isolated from both tick species, and *I. neotomae* was proven a competent enzootic vector of the Lyme disease spirochete.

2091. Kelly, Gerald D., and Woodrow W. Middlekauff. 1961. **Biological studies of *Dissosteira spurcata* Saussure with distributional notes on related California species (*Orthoptera-Acrididae*).** Hilgardia 30(14):395-424.
Abstract: A 2-year study was conducted of the California rangeland grasshopper, *Dissosteira spurcata*. This seldom-dominant species is not considered of significant economic importance to the agricultural economy of the state, but in proportion to its numbers it contributes a share of damage to rangeland forage. It has only been since the advent of chlorinated hydrocarbon insecticides that a true appreciation of the damage potentials of rangeland species has been realized. The biology and distribution of this species are described in detail. Laboratory rearing studies were conducted at constant as well as variable temperatures to show developmental patterns and to follow more closely individual characteristics and habits. The bulk of the study, however, was carried on in the field under natural conditions. In laboratory rearing experiments at a constant temperature the greatest survival and fastest development took place at 89.6°F. Survival was somewhat better when grasshoppers were reared under variable temperatures, but development was slower. Observations were made on mating, oviposition, migration, predators, parasites, and other aspects of the bionomics of spurcata.

2092. Lane, Robert S. 1974. **The biology and taxonomy of immature *Tabanidae* from Mendocino County, California, with an autecological study of *Chrysops hirsuticallus* Philip (Diptera: Tabanidae).** Ph.D. Dissertation, Univ. Calif. Berkeley. 266 pp.
Abstract: The biology and taxonomy of immatures of *Tabanidae* occurring on the Hopland Field Station and adjacent areas in Mendocino County were studied between 1971 and 1973. I examined 318.2 m^2 of soil to a depth of 8-10 cm, representing 3,421 0.093 m^2 samples, from 5 major semi-aquatic habitats (in seepage areas and above the margins of creeks, permanent ponds, temporary pools and the Russian River) and terrestrial habitats (oak woodland soil and leaf litter). These samples yielded 1,487 larval and pupal tabanids of 15 species in 4 genera. Seepage areas ranked first with respect to density and diversity, yielding an average of 15.3 immatures/m^2 of seven species. Creek margins produced the lowest density and temporary pond margins the lowest diversity among semi-aquatic habitats. Woodland soil and leaf litter yielded no tabanid immatures. I reared 13 of the 15 species collected, 10 of which had not been reared previously. Descriptions are presented of the larva and pupa of 10 species for which immatures were not previously described (7 *Chrysops*, 2 *Silvius*, 1 *Tabanus*) and redescriptions of *T. punctifer* and *T. similis* and the larvae and pupae of *T. monoensis*. Generic and specific keys were prepared for the larvae and pupae of all species encountered. Larvae and pupae of *C. coquilletti* and *C. wileyae* were indistinguishable, and evidence was obtained suggesting these species are conspecific. *C. coquilletti robustus* is not a valid subspecies because larvae obtained from the same substratum produced adults of *C. coquilletti* and *C. c. robustus*. A population of *C. hirsuticallus* was localized at a temporary pond in an area covered by chaparral and surrounded by rolling hills. The predominant vegetation types in the pond which served as oviposition sites for flies were *Eleocharis macrostachya, Eryngium aristulatum*, and *Juncus phaeocephalus*. Systematic sampling of the immatures of *C. hirsuticallus* over 15 months disclosed that this species has a 2-year life cycle. Larvae migrated horizontally inward with the receding pond margin and downward as the pond dried in late July. After fall rains refilled the pond in October or November, larvae were aquatic until February to May when they migrated above shore. Mature larvae pupated above the pond margin in April and May. Male emergence preceded that of females. Sweep collections taken twice weekly showed that *C. hirsuticallus* has a unimodal population curve with a sharp mid-May peak and a 1:1 sex ratio. The mating behavior of *C. hirsuticallus* is unique among *Tabanidae* because males actively search for teneral, virgin females. Males began seeking females between 0700-1000 (PST) when air temperatures reached 17-19°C. Coupling occurred on the ground and

UC Berkeley researcher Bob Lane examines CO_2-baited tick trap, April 1996

lasted an average of 23 minutes. The biting cycle of *C. hirsuticallus* was monophasic on a warm day (T max = 26.7°C) and biphasic on a hot day (T max = 39.5°C). The onset of biting activities began at 18°C and ceased with diminishing light intensity at sundown. Host sources of 35 blood-fed flies were determined by serological methods. Six mammalian species were identified as hosts of *C. hirsuticallus*: cattle, deer, jackrabbit, opossum, raccoon, and tentatively, woodrat. Oviposition was observed from 0940-1830 on days when temperatures reached at least 24-26°C. Significantly more flies presented a choice of the 3 principal plant species preferred to oviposit on *J. phaeocephalus* ($p < 0.01$). A parity study of *C. hirsuticallus* showed that percentage of nullipars was twice that of pars, and a small fraction of females completed 3 ovipositions. Spiders, especially *Tetragnathidae*, appeared to be the most important predators of *C. hirsuticallus* adults. A comparison of the efficiency of Tullgren funnels and a 1.5-mesh wire sieve for extracting known numbers of larvae from pond soil revealed that the sieve was more efficient than the funnels at high (i.e., 20 larvae/0.093 m^2) and low larval densities (10 larvae/0.093m^2).

***Tabanus punctifer*, the western black horse fly**

2093. Lane, Robert S. 1975. **Immatures of some *Tabanidae* (*Diptera*) from Mendocino County, California.** Ann. Entomol. Soc. Am. 68(5):803-819.
Abstract: Approximately 2,100 larval and pupal tabanids of 15 species in 4 genera were collected in Mendocino County from 1971 to 1974. Thirteen of the 15 species collected were reared to adults. Larvae and pupae of the 10 species (7 *Chrysops*, 2 *Silvius*, 1 *Tabanus*) are described for the first time and larvae and pupae of *Tabanus monoensis* are redescribed. The immatures of *T. punctifer* and *T. similis*, which were also reared, are discussed. Although larvae and pupae of *C. coquilletti* and *C. wileyae* were inseparable and reared females were difficult to distinguish, several morphological characters were found that differentiated males of these species.

2094. Lane, Robert S. 1976. **Density and diversity of immature Tabanidae (Diptera) in relation to habitat type in Mendocino County, California.** J. Med. Entomol. 12(6):683-691.
Abstract: Potential habitats of immature Tabanidae in southeastern Mendocino County, were investigated from March to July 1971-1973. Funnel extraction, handsorting, and sieve methods were used to examine 3,421 soil samples 0.093 m^2 (=1 ft^2) × 8-10 cm deep from 5 major semiaquatic habitats (in seepage areas and above the margins of creeks, permanent ponds, temporary ponds, and the Russian River) and terrestrial habitats (oak woodland leaf litter and soil). These habitats are described and compared with respect to the density and diversity of tabanid inhabitants. Semiaquatic sampling yielded 1,437 larval and pupal tabanids of 15 species on 4 genera. Seepage areas ranked first as to diversity and density, yielding an average of 15.3 immatures/m^2 of 7 species. Temporary pond margins yielded 14.4 immatures/m^2 to rank second, although only ¼ of those sampled were productive. The borders of creeks produced the lowest density (2.8 immatures/m^2) and those of temporary ponds the lowest diversity (4 species). Woodland leaf litter and soil samples yielded no tabanid immatures although they comprised over 40% of all samples. Other potential habitats sampled in which few or no tabanid immatures were found included decaying logs, stock water troughs, and treeholes. Four of the 7 species of *Chrysops* reared were each restricted to one habitat type. *Chrysops* species were most abundant in habitats containing moderate to large amounts of decaying organic matter. The larvae of *Hybomitra* spp. A and B were associated with organic substrata, principally mosses. Immatures of both *Silvius* species were collected from sand and silt above the margins of lotic habitats. *Tabanus* species were adapted to a variety of habitats, as larvae of 3 of the 4 species collected inhabited 2 or more habitat types. *T. punctifer* occurred in every kind of natural semiaquatic habitat sampled except treeholes.

2095. Lane, Robert S., and John R. Anderson. 1976. **Extracting larvae of *Chrysops hirsuticallus* (Diptera: Tabanidae) from soil: efficiency of two methods.** Ann. Entomol. Soc. Am. 69(5):854-856.
Abstract: A comparison of the efficiency of Tullgren funnels vs. a wire sieve for extracting known numbers of late instar *Chrysops hirsuticallus* from soil samples ca. 5.1 cm thick by 0.093 m revealed that the sieve was more efficient when both high (20) and low (10) larval densities were used. The difference between replicates during funnel extraction were significant at high larval density (chi square test, $p = .034$), which raises doubts about the reliability of this method for quantitative studies of larval tabanid populations.

Robert S. Lane

Adult male deer fly, *Chrysops hirsuticallus*, feeding on a monkeyflower

2096. Lane, Robert S., and Richard W. Emmons. 1977. **Ecological and epidemiological studies of tularemia in California.** Calif. Vector Views 24(11-12):39-49.
***Abstract*:** *Fransicella tularensis* was isolated in suckling and adult mice from 1/53 pools (= 2/882 individuals) of the Pacific Coast tick, *Dermacentor occidentalis,* examined during a survey for *Rickettsia rickettsi* and Colorado tick fever virus in Mendocino Co., California, 1974 - 1977. At least 7 other tick species (316 pools, 2792 ticks) and blood samples from 15 mammalian species (429 specimens) tested in suckling and adult mice were negative. A total of 271 sera representing 14 mammalian species was then selected from the survey bank and tested for *F. tularensis* agglutinating antibodies.

Sera from 4/29 (13.8%) California ground squirrels (*Spermophilus beecheyi*), 1/33 (3.0%) Columbian black-tailed deer (*Odocoileus hemionus columbianus*), and 1/51 (2.0%) black-tailed jackrabbits (*Lepus californicus*) had titers ranging from 1:20-1:80. The significance of these findings, discussion of *F. tularensis* ecology, and a brief review of 110 human cases of tularemia acquired in California from 1952 to 1977 are presented.

2097. Lane, Robert S. 1979. **Larvae and pupae of two *Hybomitra* species (Diptera: Tabanidae) from northern California.** J. Med. Entomol. 16(2):142-149.
Abstract: Larvae and pupae of *Hybomitra californica* and *H. sonomensis* from Northern California are described for the first time. A detailed morphological comparison of the immatures of *H. sonomensis* with those of *H. phaenops* from Arizona is presented, which corroborates recent adult morphological evidence that these forms are specifically distinct.

2098. Lane, Robert S., and Robert A. Murray. 1980. **Surveillance of tick-borne diseases of actual or potential public health importance in California.** Bull. Soc. Vector Ecol. 5(5):57-62.
Abstract: In California, ticks constitute the most important group of arthropods among those that transmit animal disease agents to man. Approximately 75% of the major arthropod-borne pathogens reportedly contracted autochthonously during the 1970s resulted from tick exposure, whereas mosquitoes and fleas were incriminated as the source of infection in 14% and 10% of the cases, respectively. Four hundred cases of Colorado tick fever (CTF), tick-borne relapsing fever, and Rocky Mountain spotted fever (RMsf) were reported from 1954-1979, with CTF ranking 1st with a mean of 8.8 cases/year, relapsing fever 2nd with 4.7 cases/year, and RMsf 3rd with 1.9 cases/year. Additionally, several cases of tularemia and, for the first time in the state, erythema chronicum migrans, were attributed to tick bite during this period. The surveillance program for tick-borne diseases by the California State Dept. of Health Services is summarized as well as the results of recent investigations of tick-pathogen-host interrelationships conducted primarily in western California.

2099. Lane, Robert S., and John R. Anderson. 1982. **Terrestrial breeding sites of Rhagionidae (Diptera) in northern California.** Pp. 62-64 *in:* Proc. Calif. Mosq. Vector Control Assoc., Vol. 49, Redding, CA, Apr. 26-29, 1981.
Abstract: The potential breeding sites of snipe flies in woodland-grass soils were investigated by a combination of emergence trapping and sampling for immatures in Mendocino County, California, 1978-81. Adults of 8 rhagionoid species (*Chrysophilus*, 2; *Ptiolina*, 1; *Rhagio*, 1; *Symphoromyia*, 4) were taken inside emergence traps, and immatures of *Ptiolina* spp. near *zonata* and *Rhagio costatus* were reared to adults. Seventy-one hours spent hand-sorting woodland soils in 1980-81 yielded 29 *rhagionis* immatures, or approximately 1 every 2.45 hrs. Berlese funnels and hand-sorting appeared to be almost equally efficient for extracting larvae of *Ptiolina* sp., which occupied the upper 5 cm of soil. These findings corroborate previous reports that immature snipe flies are terrestrial.

2100. Lane, Robert S., Richard W. Emmons, Dale V. Dondero, and Bernard C. Nelson. 1981. **Ecology of tick-borne agents in California. I. Spotted fever group rickettsiae.** Am. J. Trop. Med. Hyg. 30(1):239-252.
Abstract: Rocky Mountain spotted fever occurs sporadically in man in western California, a region where the classic vector, *Dermacentor andersoni,* is absent and the vector-pathogen-host interrelationships are poorly known. Therefore, from 1974-1979 we surveyed the potential mammalian hosts and tick vectors of spotted fever group (SFG) rickettsiae in northwestern California. Significant complement-fixing (CF) antibody titers of 1:16 or greater were detected in 45 of 887 sera (5 of 16 species examined). These comprised 37 of 135 black-tailed jackrabbit (*Lepus californicus*), 2 of 3 brush rabbits (*Sylvilagus bachmani*), 3 of 12 kangaroo rats (*Dipodomys californicus*), 1 of 37 brush mice (*Peromyscus boylei*) and 2 of 72 deer mice (*Peromyscus maniculatus*). Indirect fluorescent antibody (IFA) titers of ≥1:8 for SFG rickettsiae also were present in 30 of 84 *californicus* sera. Neither *D. californicus* nor *P. boylei* has been implicated previously as a host species for SFG rickettsiae. Lower CF antibody titers (1:4-1:10), suggestive of past infection but of less certain significance, were found in 46 additional sera from 9 species. A total of 4,487 ticks (418 pools) comprising 8 species were tested for the presence of rickettsiae. SFG antibodies detected by the IFA method were produced in adult mice inoculated with tick pool suspensions as follows: *Dermacentor occidentalis*, 23 of 65 pools (35.38%); *Haemaphysalis leporispalustris*, 5 of 182 pools (2.75%)*;* and *Ixodes pacificus*, 2 of 46 pools (4.35%). The positive pools of *D. occidentalis* were collected from deer or vegetation, those of *I. pacificus* from jackrabbit and raccoon. This is the first time that *I. pacificus* from California has been found associated with SFG rickettsiae. Reisolation attempts in guinea pigs, suckling mice, and/or Vero cell cultures subsequently yielded SFG rickettsiae from 4 of 22 of the tick pool suspensions found positive by the initial adult mouse-IFA screening method. Three of the isolates were recovered from *D. occidentalis* adults flagged from vegetation, and the fourth was from *H. leporispalustris* adults removed from a jackrabbit. This study supports earlier indications that in western California a mammal-tick cycle for SFG rickettsiae, different from the usual mammal-*Dermacentor andersoni* cycle for *Rickettsia rickettsi* in the western United States, exists. Further studies of the natural cycle and its implications for human disease are indicated.

2101. Lane, Robert S., Robert N. Philip, and Elizabeth A. Casper. 1981. **Ecology of tick-borne agents in California. II. Further observations on rickettsiae.** Pp. 575-584 *in:* W. Burgdorfer and R. L. Anacker (eds.), Rickettsiae and Rickettsial Diseases. Academic Press, New York.
Abstract: In California, 1,065 ticks representing 1 argasid and 6 ixodid species from 11 counties were examined for rickettsia-like organisms by hemolymph test (HT) in 1980. Of these, 181 ixodids (6 spp.) from 7 counties were HT positive. Sixty-four isolates of rickettsiae were recovered in Vero cell cultures from *Dermacentor occidentalis, D. parumapertus, D. variabilis, Haemaphysalis leporispalustris*, and *Ixodes pacificus*. These comprised 6 serotypes, 5 of which belonged to the spotted fever group (*Rickettsia rhipicephali* and 4 unclassified serotypes) and 1 of the typhus group (*R. canada*-like). Among these, only the unclassified 364D serotype, associated with *D. occidentalis*, is suspect as a cause of human illness in this state.

2102. Lane, Robert S., and John R. Anderson. 1982. **Breeding sites of snipe flies (Rhagionidae) and other Diptera in woodland-grass soils.** J. Med. Entomol. 19(1):104-108.
Abstract: During terrestrial surveys for immature and adult rhagionids in Mendocino County, woodland-grass soils were found to be a breeding source for 8 species of snipe flies: *Chrysophilus*, 2; *Ptiolina*, 1; *Rhagio*, 1; and *Symphoromyia*, 4. Immatures of *Ptiolina* sp. near *zonata* obtained by hand sorting moss-covered soil samples from 1978-1980 yielded two adults. This is apparently the first time that *Ptiolina* has been reported from the state and that *Ptiolina* immatures have been successfully reared in the Nearctic region. Adults of 8 rhagionoid species were collected in emergence traps from April to July and in December 1980, with emergence densities ranging from 0.04 individuals/m^2 for *S. conspicua* to 1.30/m^2 for *Ptiolina* spp. Emergence traps also captured miscellaneous dipterans belonging to ca. 48 species in 20 families. Incidental to other studies, a single male of an undescribed species of *Symphoromyia* near

truncata was taken in an emergence trap in Contra Costa County.

2103. Lane, Robert S., and John R. Anderson. 1982. **The reproductive life history and blood meal sources of *Chrysops hirsuticallus* (Diptera: Tabanidae).** J. Med. Entomol. 19(2):157-163.
Abstract: The reproductive life history and blood meal sources of the deer fly *Chrysops hirsuticallus* from Mendocino County, were determined during 1971 - 1974. Nulliparous specimens predominated in late April and most of May, whereas uniparous and biparous flies constituted the majority of the late May - June collections. Two triparous flies observed in 1973 are the first recorded for wild-caught deer flies in North America. Egg retention increased with advancing gonotrophic age. Sweeping of vegetation yielded comparable proportions of females with their terminal follicles in developmental stages N to II (55%) and III to V (45%), with 85% of the flies in stages II or V. More than 80% of flies hand-captured while attacking man were in stage II, whereas only 2% were in stages III to V. *C. hirsuticallus* is anautogenous at this site, since females reared from pupae and held alive for up to 8 days entered ovarian diapause in stage II by day 4. Mating preceded blood feeding, as spermathecae of all 17 host-seeking nullipars examined contained spermatozoa. Serologic analyses (capillary precipitin and passive hemagglutination inhibition tests) of 19 engorged specimens revealed that cattle and Columbian black-tailed deer were frequent hosts. Limited feeding also occurred on black-tailed jackrabbit, Virginia opossum, and raccoon.

2104. Lane, Robert S., Richard W. Emmons, Veronica Devlin, Dale V. Dondero, and Bernard C. Nelson. 1982. **Survey for evidence of Colorado tick fever virus outside of the known endemic area in California.** Am. J. Trop. Med. Hyg. 31(4):837-843.
Abstract: A virus very similar or identical to Colorado tick fever (CTF) virus was recovered from the blood clot of one of 104 black-tailed jackrabbits (*Lepus californicus*) examined during a survey for various zoonotic agents in mammals and ticks from the Hopland Field Station, 1974-1979. This is the first reported isolation of CTF-like virus from *L. californicus*, and only the second time such a virus has been found in northwestern California. Mendocino County is located far outside the known distributional ranges of the most common mammalian hosts of CTF virus and or *Dermacentor andersoni*, the only proven tick vector for man. The viral isolate is very similar to a CTF-like virus previously recovered from the blood and spleen of a western gray squirrel from San Luis Obispo County, an area also outside the previously-known CTF area. The virus was not isolated from 14 additional species of mammals (354 specimens) or from 8 species of ticks (4,487 individuals), but CTF-neutralizing antibodies were detected in 28 of 771 (3.6%) sera from seven of 15 mammalian species including significant titers (≥1:8) in 2 species and one subspecies not previously reported as natural hosts, i.e. brush mouse, piñon mouse, and Columbian black-tailed deer. CTF indirect immunofluorescence antibodies also were detected in 26 of 129 (20.2%) sera belonging to 4 of 5 mammalian species tested. Neutralizing antibodies were found in sera of deer from other localities in Mendocino County, from a deer mouse in Napa County, and from a brush rabbit from Monterey County as well. These finding suggest that a virus identical or similar to CTF virus is widespread in northwestern-westcentral California, and that surveillance for human cases of CTF or a similar disease should be extended to cover this region.

2105. Lane, Robert S., and John R. Anderson. 1984. **Efficacy of permethrin as a repellent and toxicant for personal protection against the Pacific Coast tick and the Pajaroello tick (Acari: Ixodidae and Argasidae).** J. Med. Entomol. 21(6):692-702.
Abstract: The repellency and toxicity of permethrin as a clothing impregnant was tested against adults of the Pacific Coast tick, *Dermacentor occidentalis*, and nymphs and adults of the Pajaroello tick, *Ornithodoros coriaceus*, under field and laboratory conditions. When offered a choice of permethrin-treated (5.7-12.8 µg AI / cm^2) vs. untreated cotton surfaces to crawl on, most individuals of both ticks gravitated toward the untreated surface within 1-2 min. This apparent initial repellency wore off gradually (8-15 min) in *D. occidentalis* and more rapidly (4-8 min) in *O. coriaceus*. Exposure of *D. occidentalis* to cotton surfaces treated with ca. 3.8-5.4 µg AI / cm^2 for 75 s caused 92% and 100% morbidity / mortality within 1 and 22 h, whereas exposure of *O. coriaceus* to similar concentrations for only 45 s produced 48% and 100% morbidity / mortality within 1 and 24 h. A comparison of the number of *D. occidentalis* ticks collected from humans wearing treated vs. untreated overalls as they walked through tick-infested chaparral-grassland revealed that 14% fewer ticks were found on the treated clothing, but this difference was not significant. The difference in the morbidity / mortality 1 day later of ticks removed from the treated and untreated overalls (60% vs. 3%) was highly significant. When *D. occidentalis* adults (n = 40) were placed on the midshin region of untreated overalls (worn by standing objects) or those containing <3 µg permethrin / cm^2, 35-45% of the ticks crawled up to various points between the knee and waistline within 15 min, and all were still healthy 1 h later. In contrast, 90% of the adults (n = 20) similarly placed on overalls treated with 4 µg AI / cm^2 did not crawl up to the knee or beyond within 15 min, and 94% (n = 18) were morbid 1 h later. Preliminary attempts to determine the effectiveness of permethrin for personal protection against *O. coriaceus* ticks under field conditions were unsuccessful, apparently because of unfavorable weather conditions.

Engorged female Pacific Coast tick on a deer

2106. Lane, Robert S., John R. Anderson, J. S. Yaninek, and Willy Burgdorfer. 1985. **Diurnal host seeking of adult Pacific Coast ticks, *Dermacentor occidentalis* (Acari: Ixodidae), in relation to vegetational type, meteorological factors, and rickettsial infection rates in California, USA.** J. Med. Entomol. 22(5):558-571.
Abstract: Diurnal host seeking activities of *Dermacentor occidentalis* adults in chaparral and grassland were evaluated by flagging vegetation and with CO_2 (dry ice)-baited traps in Mendocino County, California, in 1982-1983. Ecotonal chaparral yielded significantly more ticks by flagging than did chaparral on south-facing slopes, and tick abundance was higher on south- than on north-facing slopes. Ticks did not exhibit any specificity with regard to chaparral plants selected at questing sites. Regression analyses revealed that temperature, relative humidity, and solar radiation, either singly or in a combination, usually did not explain a significant amount of the total daytime variation in tick numbers. Flagging demonstrated that adults were aggregated at the chaparral-grassland ecotone and that their numbers diminished markedly within 3-5 m on either side of it. Tick infection rates with rickettsia-like organisms and spotted fever group rickettsiae did not differ significantly by sex or exposure (north vs. south facing slopes). An evaluation of the

drag method as to efficiency, drag size, and potential impact on localized populations in chaparral revealed it was reasonably efficient, that drag sizes of 0.46 and 0.92 m^2 produced comparable results, and that weekly flagging for 1.5 months did not consistently reduce tick numbers in ecotonal chaparral. In contrast, the CO_2 trap method yielded relatively low numbers of ticks in chaparral, ecotone, and grassland (in descending rank), with much variation between samples. Mark-recapture experiments with CO_2-baited pitfall traps demonstrated that the effective radius for collecting adults in chaparral was 4 m; 30.5% of the 200 ticks released within 0.5-4.0 m of the trap were recovered in 4 hours of trapping. Only 4 (2.5%) of 160 ticks released 5-12 m from the trap were recaptured in 12 hours of trapping.

2107. Lane, Robert S., Willy Burgdorfer, Stanley F. Hayes, and Alan G. Barbour. 1985. **Isolation of a spirochete from the soft tick, *Ornithodoros coriaceus:* a possible agent of epizootic bovine abortion.** Science 230:85-87.
Abstract: A *Borrelia*-like spirochete was detected in all 3 parasitic stages of *Ornithodoros coriaceus,* the soft tick implicated in the epizootic bovine abortion. After the spirochete had been isolated, its distinctness from other north American tick-borne borreliae as well as from *Spirochaeta aurantia, Treponema pallidum*, and *Leptospira interrogans* serovar *pomona* was established on the basis of its morphology, protein components, and inability to infect mice. The spirochete is passed transstadially and via eggs by ticks, and it is also excreted in coxal fluid after ticks have fed and detached. Circumstantial evidence suggests that the spirochete may be casually related to epizootic bovine abortion.

2108. Lane, Robert S., and George O. Poinar Jr. 1985. **Biology and description of the larval horse fly host (Diptera: Tabanidae) of a *Pheromermis sp.* (Nematoda: Mermithidae).** Myia 3:463-474.
Abstract: In North America, larvae of *Chrysops*, *Hybomitra*, and *Tabanus* species have been found naturally infected with mermithid nematodes on several occasions, but only a single species, *Pheromermis myopis*, has been described previously. Records of mermithid parasitism of larval tabanids from other continents have been previously reviewed. More recently, two new species of mermithids, *Pheromermis tabani* and *P. vernalis*, that parasitized larvae of *Tabanus autumnalis* in the Soviet Union, were described. This communication provides descriptive details concerning the biology and taxonomy of a *Hybomitra* species that is parasitized by a mermithid nematode closely related to *P. myopis.* Some morphologic characteristics of the nematode are also given, as is a brief comparison with other species in the genus *Pheromermis.* Late instars of a horse fly, *Hybomitra* sp., from northern California, are described for the first time. Nearly 40% of the *Hybomitra* larvae from an intermittent spring seepage at the Hopland Field Station, in Mendocino County, were parasitized by mermithid nematodes, *Pheromermis* sp. near *myopis*. A few *Hybomitra* larvae from other intermittent habitats (creek and spring seepage) also were found infested with nematodes. *Hybomitra* sp. is the only second member of the genus from North America to be found infested with mermithid nematodes.

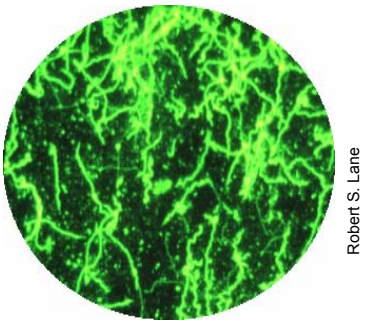
2109. Lane, Robert S., and Willy Burgdorfer. 1986. **Potential role of native and exotic deer and their associated ticks (Acari: Ixodidae) in the ecology of Lyme disease in California, USA.** Zbl. Bakt. Hyg. A 263:55-64.
Abstract: The relationship of native Columbian black-tailed deer (*Odocoileus hemionus*), two species of exotic deer (axis and fallow, *Axis axis* and *Dama dama*), and their ticks to the Lyme disease spirochete, *Borrelia burgdorferi*, was studied in coastal and inland areas of northern California. Spirochetemias were detected in 27% of black-tailed deer, 50% of axis deer, and 56% of fallow deer collected in the late fall and winter. Antibody prevalence was 38% in black-tailed deer, 24% in fallow deer, and 6% in axis deer. One to 3 tick species were collected from each species of deer, and 2 tick species were flagged from vegetation; of these, only the western black-legged tick*, Ixodes pacificus*, was found to contain spirochetes. These findings suggest that all 3 deer species may be important hosts of spirochetes, possibly *B. burgdorferi*, and reconfirm that *I. pacificus* is the primary vector of the latter in California.

2110. Lane, Robert S., and Willy Burgdorfer. 1987. **Transovarial and transstadial passage of *Borrelia burgdorferi* in the western black-legged tick, *Ixodes pacificus* (Acari: Ixodidae).** Am. J. Trop. Med. Hyg. 37(1):188-192.
Abstract: Transovarial and transstadial passage of *Borrelia burgdorferi* was demonstrated for the first time in the western black-legged tick, *Ixodes pacificus*. One of 3 field-collected females with spirochetes in ovarial tissues produced 100% infected progeny that maintained the spirochetes transstadially and in 4 of 5 cases passed them via eggs to as many as 97% of F_2 filial ticks. The progeny infected ovarially and by subsequent transstadial passage had generalized tissue infections that exhibited reduced immunofluorescence staining reactivity with a fluorescein isothiocyanate-labeled polyclonal antibody. Attempts to isolate the spirochete from ticks in BSK medium or various modifications of it were unsuccessful. Spirochetes in tissue smears of all 3 parasitic stages of the F_1 generation were nonreactive with a monoclonal antibody (H5332) specific for *B. burgdorferi*, whereas those present in tissue smears of F_2 larvae bound with it.

2111. Lane, Robert S., and Willy Burgdorfer. 1988. **Spirochetes in mammals and ticks (Acari: Ixodidae) from a focus of Lyme borreliosis in California.** J. Wildl. Dis. 24(1):1-9.
Abstract: In northern California, antibodies to *Borrelia burgdorferi* were detected in 58 of 73 (79%), and spirochetemias in 1 of 26 (4%) black-tailed jackrabbits (*Lepus californicus*) by indirect and direct immunofluorescence, respectively. Five species of ticks (*Dermacentor occidentalis, D. parumapertus, Ixodes neotomae, I. pacificus*, and *Haemaphysalis leporispalustris*) were collected from rabbits. Two of these species of ticks were found to contain spirochetes; 2 of 10 (20%) *I. neotomae*, and 2 of 174 (1%) *H. leporispalustris*. A strain of *B. burgdorferi* was recovered from *I. neotomae*. One infected *H. leporispalustris* female passed spirochetes via eggs to about 67% of her progeny. The widespread distribution of the black-tailed jackrabbit, its infection by at least 4 ticks (*D. occidentalis, D. parumapertus, I. neotome*, and *I. pacificus*) known to be infected naturally with *B. burgdorferi*, and the high prevalence of spirochetal antibody in this lagomorph suggest that it might be useful as a sentinel for surveillance of Lyme borreliosis. Spirochetes were detected in 15% of 40 Columbian black tailed deer (*Odocoileus hemionus columbianus*) by direct immunofluorescence bound with a *Borrelia*-specific monoclonal antibody (H9724), but not with a monoclonal antibody (H5332) specific for *B. burgdorferi*. The geographical overlap of different borreliae in ticks that bite wildlife such as deer may confound spirochetal serosurveys, and underscores the need for more specific serologic tests than those currently available.

2112. Lane, Robert S., and Paul E. Lavoie. 1988. **Lyme borreliosis in California: acarological, clinical, and epidemiological studies.** Lyme Disease and Related Disorders. Annals N. Y. Acad. Sci. 539:192-203.
Abstract: The relative abundance of, and spirochetal-infection rates in, adult ixodid ticks from 8 Lyme borreliosis clinical-case areas and 2 comparison areas were investigated in northern California from late fall to early spring, 1984-1987. The western black-legged tick (*Ixodes pacificus*) was the most abundant species at 7 of 9 sites yielding specimens as determined with a tick drag method. The Pacific Coast tick, *Dermacentor occidentalis*, was the most abundant

species at 2 sites, and lesser numbers of this tick and the American dog tick, *D. variabilis*, were obtained from 7 and 2 sites, respectively. Abundance of *I. pacificus* adults varied in clinical-case areas as well as in the comparison areas, and was not correlated significantly with spirochetal infection rates in this tick. Overall, spirochetes were detected in 1.4 and 1.0% of the adult *I. pacificus* collected from clinical case (n = 857) and comparison sites (n = 383), respectively, and in 0.8% of adult *D. occidentalis* (n = 253) from one comparison area. An additional 244 *D. occidentalis* adults from all other sites were tested with negative results. Five spirochetal isolates recovered from *I. pacificus* adults were identified as *Borrelia burgdorferi* with specific monoclonal antibodies. Seven of 10 patients interviewed reportedly contracted their infections in summer, and 6 presented with a history of a tick bite. Nine patients owned or occasionally harbored one or more dogs, and at least one of the dogs contracted Lyme borreliosis at the same site as its owner. Clinical manifestations of the disease in human patients included erythema migrans (100%), arthritis/arthralgia (60%), neurologic abnormalities (60%), and cardiac involvement (20%). Four of 9 patients whose sera were assayed by indirect immunofluorescence contained significant antibody titers to *B. burgdorferi.*



The Lyme disease spirochete *Borrelia burgdorferi*

2113. Lane, Robert S., and Stephen A. Manweiler. 1988. ***Borrelia coriaceae* in its tick vector, *Ornithodoros coriaceus* (Acari: Argasidae), with emphasis on transstadial and transovarial infection.** J. Med. Entomol. 25(3):172-177.
Abstract: Field and laboratory studies demonstrated that transovarial passage of the recently-described spirochete *Borrelia coriaceae* occurs occasionally in the soft tick *Ornithodoros coriaceus*, but this process appeared to be inefficient for maintaining and distributing the spirochete. Borreliae were detected in only 5 (0.6%) of 883 wild-caught *O. coriaceus* larvae and in a low percentage of the F_1 larval progeny from only one of 9 spirochete-infected females. Infected and uninfected females did not differ statistically in fecundity or fertility. Transstadial survival of spirochetes also occurred in *O. coriaceus*, but experimental evidence suggests that some ticks may lose their infections during or after ecdysis. The distribution of spirochetes in tissues of infected nymphs and adult ticks that fed to repletion and later molted or oviposited was generalized or semigeneralized. Neither the coxal fluid nor the hemolymph test was found to be reliable for detecting spirochetes in ticks. Borreliae in tissue smears prepared from 1 of 18 spirochete-infected *O. coriaceus* nymphs and adults reacted with a monoclonal antibody (H5332) that is reportedly specific for *Borrelia burgdorferi*. The potential significance of this finding is discussed briefly.

2114. Lane, Robert S., and Jenella E. Loye. 1989. **Lyme disease in California: interrelationship of *Ixodes pacificus* (Acari: Ixodidae), the western fence lizard (*Sceloporus occidentalis)*, and *Borrelia burgdorferi*.** J. Med. Entomol. 26(4):272-278.
Abstract: The relationship of immature western black-legged ticks, *Ixodes pacificus*, to the western fence lizard, *Sceloporus occidentalis*, and to the Lyme disease spirochete, *Borrelia burgdorferi*, was investigated in chaparral and woodland-grass habitats in northern California from 1984 to 1986. Immature ticks were found on lizards in spring and summer, but the prevalence and abundance of ticks on this host were considerably greater in spring. The peak of larval abundance preceded that of nymphs by several weeks, but there was considerable seasonal overlap between these parasitic stages. Larvae and nymphs attached primarily to the lateral nuchal pockets of lizards in chaparral (99.5%) and woodland-grass (91.8%). The numbers of larvae infesting lizards in spring fit the binomial distribution in woodland-grass but not in chaparral; insufficient data precluded similar analyses for nymphs. Tick loads did not differ significantly with respect to age or gender of the lizard. Spirochetal infection rates (range 0-3.7%*)* in *I. pacificus* immatures were comparable in both habitats and were similar to those reported previously for adults of this tick. Overall, 1 (0.9%) of 117 larvae and 10 (1.8%) of 552 nymphs were infected with spirochetes resembling *B. burgdorferi*. Spirochetes were not observed in blood smears prepared from 260 wild-caught lizards, including 5 lizards fed upon by infected ticks at the time of collection. These and other findings suggest that *S. occidentalis*, although an important host of *I. pacificus* immatures, may be less important as a source for infecting with *B. burgdorferi*.

2115. Lane, Robert S., and Judith A. Pascocello. 1989. **Antigenic characteristics of *Borrelia burgdorferi* isolates from ixodid ticks in California.** J. Clin. Microbiol. 27(10):2344-2349.
Abstract: Twenty (1.4%) of 1,421 adult *Ixodes pacificus* ticks and 2 (20%) of 10 adult *Ixodes neotomae* ticks collected in 5 counties in northern California were found to contain spirochetes by direct immunofluorescence examination of their tissues with a polyvalent conjugate. Borreliae isolated from the tissue of 9 of these ticks (*I. pacificus*, 8; *I. neotomae*, 1) were identified as *Borrelia burgdorferi* with specific mononuclonal antibodies and characterized further by polyacrylamide gel electrophoresis and western blot (immunoblot) analyses. The isolate from *I. neotomae* was the first to be characterized from a tick other than *I. pacificus* in western North America. All strains were relatively homogeneous with respect to the kind of OspA proteins they produced, whereas they were heterogeneous with regard to their OspB proteins and to several low-molecular-weight proteins in the 21,500 to 24,000 region. Significant phenotypic variation was observed among isolates obtained within and between populations of *I. pacificus*. This investigation nearly doubles the number of isolates of *B. burgdorferi* that have been characterized from ixodid ticks in the far western United States.

2116. Lane, Robert S., and David C. Regnery. 1989. **Lagomorphs as sentinels for surveillance of borreliosis in the far western United States.** J. Wildl. Dis. 25(2):189-193.
Abstract: Brush rabbits and black-tailed jackrabbits from California were assayed for antibodies to *Borrelia burgdorferi*, the etiological agent of Lyme borreliosis. Significant antibody titers were detected in 90% (range, 67% to 100%) of brush rabbits from 4 of 6 localities, and in 90% of jackrabbits from a single locality, in northern California. One of the populations of brush rabbits that did not yield seropositive individuals inhabited an oceanic island devoid of any other terrestrial mammals, whereas the other population was located on an isolated flood plain bordering San Francisco Bay. Absorption tests using *B. burgdorferi* as antigen revealed that antibodies detected in both species of lagomorphs were detected against borreliae. These findings reinforce the earlier suggestion that lagomorphs may be useful as sentinel animals for surveillance of borreliosis in the far western United States.

2117. Lane, Robert S. 1990. **Lyme disease, with emphasis on the western U.S. and its relationship to wildlife (Abstract).** P. 35 *in:* Proc. 14th Vertebr. Pest Conf. (L. R. Davis and R. E. Marsh, eds.),

Univ. Calif. Davis, Sacramento, CA, Mar. 6-8.
Abstract: In the western United States, Lyme disease has been reported primarily from the three Pacific states, especially California, and sporadically or not at all from various mountain states. In California, surveillance for Lyme disease was initiated in 1983, but it was not made a reportable disease in this state until 1989. Nevertheless, approximately 400 human cases were reported by California state health authorities between 1983 and 1987. In 1982, I began studying the ecology and epidemiology of Lyme disease in the far-western United States in collaboration with Dr. Willy Burgdorfer of the Rocky Mountain Laboratories, Hamilton, Montana, and others. The objectives of this research have been to determine how the Lyme disease spirochete, *Borrelia burgdorferi* (Bb), is maintained and distributed in natural foci including the routes of transmission to humans and other animals. Five species of ticks have been found infected naturally with Bb or other related borreliae during these studies, but of these only the western black-legged tick, *Ixodes pacificus*, has been implicated as a vector to humans. Transovarial and transstadial passage of Bb has been demonstrated in this tick, though the efficiency of these processes for maintenance of the spirochete is still being evaluated. Western fence lizards (*Sceloporus occidentalis*) and Columbian black tailed deer (*Odocoileus hemionus columbianus*) were found to be major hosts of sub-adult and adult *I. pacificus*, respectively. Antibodies to Bb, spirochetemias, or both, have been detected in eight species of wildlife in California (western fence lizard, 2 species of lagomorphs, 2 species of rodents, 3 species of deer). Species exhibiting the highest seropositivity rates (titers $\geq$ 1:64) include brush rabbits ($\leq$ 100%) and black tailed jackrabbits ($\leq$ 90%). The widespread distribution of jackrabbits in the west, their prolific breeding habits, infestation by several species of ticks known to harbor Bb, and the high seropositivity rates render them suitable as sentinel animals for surveillance of Lyme disease. The reservoir competencies of some of these species of wildlife including Columbian black-tailed deer, and the vector competencies of their associated ticks, are currently under investigation.

2118. Lane, Robert S. 1990. **Seasonal activity of two human-biting ticks.** Calif. Agric. 44(2):23-25.
Abstract: In northern California, the western black-legged tick *Ixodes pacificus* is considered the primary vector of the spirochete *Borrelia burgdorferi* that causes Lyme disease. That tick and the Pacific Coast tick, *Dermacentor occidentalis*, also can be carriers of several other diseases. In one study, we sought to learn when humans and other animals are at greatest risk of exposure. Collections from Hopland Field Station and Sierra Foothill Range Field Station showed adults of both tick species were most abundant during the cooler seasons, although considerable variation was seen between sites and within years. Other climatological factors besides temperature such as solar radiation, relative humidity, and day-length, either singly or in combination, may influence host-seeking by such ticks. Western black-legged ticks were similar in abundance at both Hopland and Sierra, but Pacific Coast ticks were much more numerous in chaparral at Hopland than in grassland at Sierra (where chaparral is scarce). The annual activity periods of adults of these two ticks span several seasons, particularly fall to sparing, but the western black-legged tick usually reaches its greatest abundance in mid to late winter, while Pacific Coast tick populations normally peak in late winter to early spring. Recent collection records demonstrate that nymphs of these ticks bite humans more often than was realized previously. Moreover, spirochete-infection rates in nymphs of the western black-legged tick are sometimes comparable to those in adult ticks. Both species of ticks are known vectors of number of additional diseases of human and veterinary importance.

2119. Lane, Robert S. 1990. **Susceptibility of the western fence lizard (*Sceloporus occidentalis*) to the Lyme borreliosis spirochete (*Borrelia burgdorferi*).** Am. J. Trop. Med. Hyg. 42(1):75-82.
Abstract: Attempts to infect juvenile and adult western fence lizards (*Sceloporus occidentalis*) with the Lyme borreliosis spirochete (*Borrelia burgdorferi*) were largely unsuccessful. Spirochetes could not be isolated from blood and various tissues of 14 lizards 21-32 days after they had been inoculated ip (n = 8) or sc (n = 6) with 10^6 or 10^8 *B. burgdorferi* representing 3 tick isolates, although one lizard apparently developed a transitory spirochetemia lasting 2 days. Similarly, spirochetes could not be detected in the blood or tissues of 5 lizards fed upon by 2 - >8 infected larvae or nymphs or the western blacklegged tick (*Ixodes pacificus*). Sixty-five blood samples from 59 lizards in endemic area and various tissues from 20 of the same lizards were also assayed for *B. burgdorferi* with negative results. The implications of these findings for the maintenance of this spirochete in natural foci are discussed.

2120. Lane, Robert S., and H. A. Stubbs. 1990. **Host-seeking behavior of adult *Ixodes pacificus* (Acari: Ixodidae) as determined by flagging vegetation.** J. Med. Entomol. 27(3):282-287.
Abstract: Diurnal host-seeking by adults of the western black-legged tick, *Ixodes pacificus*, in relation to vegetative habitat type and meteorological factors was investigated at a coastal and an inland site in northern California. Host-seeking behavior and relative tick abundance were determined with a tick drag method from late fall to midwinter 1987-1988. At the inland site, tick abundance usually was significantly greater in chaparral-grassland ecotone than in adjoining dense chaparral on the south-facing slope of a mountaintop, whereas both of these vegetative types produced significantly fewer ticks on a north slope compared with a contiguous south-facing slope. There was no evidence for an association between tick abundance and plant species with ecotonal chaparral. Multiple regression analyses revealed that tick abundance in ecotonal chaparral at the inland site and in grassland at the coastal site was not associated consistently with either ambient temperature or relative humidity. Compared with the inland site, ticks were considerably more abundant at the coastal site where sampling occasionally yielded more than 100 ticks per 100 drag samples. The incidence of infection with *Borrelia burgdorferi*, the etiological agent of Lyme borreliosis, in adult ticks collected in the morning (1.5%) versus afternoon (2.2%) and in male (1.3%) versus female (2.5%) at the coastal site in winter was similar.

2121. Lane, Robert S., and Richard N. Brown. 1991. **Woodrats and kangaroo rats: potential reservoirs of the Lyme disease spirochete in California.** J. Med. Entomol. 28(3):299-302.
Abstract: The etiological agent of Lyme disease, *Borrelia burgdorferi,* was isolated repeatedly from dusky-footed woodrats, *Neotoma fuscipes* and California kangaroo rats, *Dipodomys californicus* in northern California. All animals were collected in a region endemic for Lyme disease but for which the natural reservoir of *B. burgdorferi* was unknown. Similar attempts to isolate spirochetes from lizards, other species of rodents, jackrabbits, and deer between 1987 and 1991 were unsuccessful. Spirochetes isolated from woodrats and kangaroo rats were antigenically similar to strains of *B. burgdorferi* that had been isolated previously from the western black-legged tick, *Ixodes pacificus*, in California. Similar enzootic cycles involving woodrats or kangaroo rats should be sought in other regions of the United States where the reservoirs of this spirochete are unknown.

2122. Lane, Robert S., and Jenella E. Loye. 1991. **Lyme disease in California: interrelationship of ixodid ticks (Acari), rodents, and *Borrelia burgdorferi*.** J. Med. Entomol. 28(5):719-725.
Abstract: The association of immature ixodid ticks, several species of rodents, and the Lyme disease spirochete, *Borrelia burgdorferi* was studied in two habitats in northern California in spring and summer 1985 and year-round in 1986. A total of 428 rodents were collected from ecotonal chaparral and a woodland-grass outcrop; the former habitat yielded 6 species, the latter 3 species. The deer

mouse, *Peromyscus maniculatus*, and the piñon mouse, *P. truei* were the dominant species year round and collectively comprised 78% of rodents captured within chaparral and 87% from the rock outcrop in 1986. In both habitats, rodents were trapped most frequently in winter and spring, and least often in summer and fall. A total of 306 rodent blood films from all 6 species were assayed for spirochetes by direct immunofluorescence; of these, only one film prepared from *P. truei* (n = 123 films from 53 individual mice) was found to contain spirochetes. Immature western black-legged ticks, *Ixodes pacificus*, and Pacific coast ticks, *Dermacentor occidentalis*, were collected from each species of rodent. Larvae of *I. pacificus* infested *P. maniculatus* and *P. truei* in low numbers year-round, but nymphs of this tick rarely parasitized these rodents. *D. occidentalis* larvae infested *P. maniculatus* and *P. truei* in spring and particularly in summer; nymphal ticks infested these mice primarily in summer. The efficiency of visual inspection for collecting immatures of these ticks from *P. maniculatus* ranged from 45% to 69% in spring and summer, whereas efficiency of a drop-off technique appeared to be 100%. Spirochetes were detected in <1% of *D. occidentalis* larvae (n = 310) and nymphs (n = 120), and in ~4% of *I. pacificus* larvae (n = 75) derived from these hosts. The potential significance of these findings in enzootiology of *B. burgdorferi* is discussed.

2123. Lane, Robert S., J. Piesman, and Willy Burgdorfer. 1991. **Lyme borreliosis: relation of its causative agent to its vectors and hosts in North America and Europe.** Ann. Rev. Entomol. 36:587-609.

Abstract: Changing land-use patterns during the second half of the 20th Century appear to have provided an environmental mosaic suitable for wildlife and *Ixodes dammini* to thrive in parts of the northeastern and midwestern U.S. Critical hosts for the enzootic cycle of *I. dammini*-transmitted *B. burgdorferi* include the white-footed mouse (*Peromyscus leucopus*) as a host for immature ticks and as a reservoir of the spirochete and white-tailed deer as a host for adult *I. dammini*. The nymphal stage of *I. dammini* seems to be primarily responsible for transmission of the Lyme disease spirochete. In western North America and Texas, 10 species of ixodid ticks and, provisionally, a single argasid tick contain *B. burgdorferi* or closely related spirochetes, but the relations of only 2 of these ticks to their associated spirochetes have been studied. In the Far West, *I. pacificus* appears to be the primary vector of *B. burgdorferi* to humans. Although research is being conducted in California to elucidate the vector competencies of *I. pacificus*, *Dermacentor occidentalis*, and several other ticks, similar studies are needed in other regions including the Pacific Northwest and western Canadian provinces. Likewise, the relations of these ticks to their vertebrate hosts and the reservoir competencies of such hosts for *B. burgdorferi* have received little or no attention in most western states or provinces except for northern California. Recent field and laboratory evidence suggest that the heavy utilization of western fence lizards as hosts by *I. pacificus* in parts of the Far West may be one of several biologic factors contributing to the low spirochete-infection rates reported for this tick. The sheep tick, *I. ricinus*, the most common tick in Europe, is the primary vector of *B. burgdorferi* on that continent. Like the related American *Ixodes* ticks, *I. ricinus* has a broad host range and most unfed, infected individuals of this tick harbor spirochetes in their midguts only. Various species of *Apodemus* and *Clethrionomys* rodents appear to serve as long-term sources of *B. burgdorferi* infection for noninfected *I. ricinus* larvae that feed on them. Although *I. ricinus* is unquestionably one of the best-studied ticks worldwide, much still remains to be learned about its role in the epizootiology of Lyme borreliosis in Europe and elsewhere.

2124. Lane, Robert S. 1992. ***Borrelia burgdorferi* in ticks on Angel Island, California: low risk of human infection.** Bull. Soc. Vector Ecol. 17(1):75-82.

Abstract: The human risk of exposure to ticks and Lyme disease was assessed at Angel Island State Park, a heavily used recreational area in San Francisco Bay, and at two comparison areas on the California mainland. To evaluate risk, a questionnaire was distributed to outdoor workers in all 3 locations to determine their exposure histories to ticks and tick-borne diseases. Also, a tick-spirochete survey was conducted on Angel Island to determine the relative abundance of human-biting ticks and the prevalence of spirochetal infection in such ticks. None of the 5 outdoor workers on Angel Island reported a history of a tick bite, whereas, 15 workers in the comparison areas averaged between 0.1 and 0.2 tick bites/year, and one individual experienced a relapsing fever-like illness. Two human biting ticks, *Ixodes pacificus* and *Dermacentor occidentalis*, were collected on Angel Island. Four (0.27%) of 1,464 *I. pacificus* adults versus zero of the 25 *I. pacificus* subadults and 183 *D. occidentalis* adults were found to contain spirochetes; spirochetal infection rates determined previously in *I. pacificus* adults from both comparison areas were somewhat higher (0.86-1.35%). One of the infected ticks from Angel Island yielded an isolate of *Borrelia burgdorferi*, the first from an island in western North America. This isolate was determined to be similar antigenically to tick-derived isolates from the adjacent mainland. Collectively, these findings demonstrate that the risk of being bitten by ticks and acquiring Lyme disease is low in all 3 localities, but it is lowest on Angel Island.

2125. Lane, Robert S. 1992. **Effect of transovarially and transstadially-passed Lyme disease spirochetes on the developmental and reproductive biology of *Ixodes pacificus* (Acari: Ixodidae).** Pp. 282-289 *in:* Proc. 1st Int. Conf. Tick-Borne Pathogens, Univ. Minn. College of Agric. and Minn. Extension Service, St. Paul, MN, Sept. 15-18.

Abstract: Transovarial transmission, the passage of a microbial agent via the eggs of an infected arthropod to the next generation, has been documented for several tick vectors of the Lyme disease spirochete, *Borrelia burgdorferi*. Transovarial transmission can occur in *Ixodes pacificus*, though evidence suggests that it is an inefficient process for maintaining and distributing spirochetes in populations of this vector tick. Further, ovarially-passed spirochetes may significantly reduce the fecundity and fertility of *I. pacificus* by the second filial generation. Heretofore, the pathologic effects of ovarially passed *B. burgdorferi* had been investigated only with respect to *I. dammini*. Additional studies of the relationship of the Lyme disease spirochete to its growing list of confirmed and putative vector ticks are needed at the molecular, cellular, and population levels.

2126. Lane, Robert S. 1994. **Ch. 3. Competence of ticks as vectors of microbial agents with an emphasis on *Borrelia burgdorferi*.** Pp. 45-67 *in:* D. E. Sonenshine and T. N. Mather (eds.), Ecological Dynamics of Tick-borne Zoonoses. Oxford University Press, New York and Oxford.

Abstract: A variety of intrinsic and extrinsic factors that affect the vector competence of argasid (soft) and ixodid (hard) ticks for microbial agents are discussed, with an emphasis of the relation of the Lyme disease spirochete, *Borrelia burgdorferi,* to its ixodid vector ticks. Vector competence and vertebrate reservoir competence are mutually dependent phenomena. Furthermore, vector competence must be viewed in the context of the interactive effects of populations of three groups of organisms: the vector(s), the agent(s), and the reservoir host(s). Competent vector ticks feed abundantly on vertebrate reservoir hosts at a time of year when the reservoirs are in an infective state, readily acquire and preserve the microbial agent in their tissues for prolonged periods, efficiently pass the agent transstadially, and effectively transmit the agent while feeding later on susceptible vertebrates. The degree of competence may vary even within populations of an efficient vector inasmuch as not all infected ticks, even those that are heavily infected with an

agent, are capable of transmitting it. The vector competence of only 10 of the ~23 species of ticks that have been found infected naturally with the Lyme disease spirochete has been evaluated so far. Of these, all 7 *Ixodes* spp. have been determined to be efficient vectors of *B. burgdorferi,* whereas 3 species of *Amblyomma* or *Dermacentor* appear to be inefficient vectors. These findings suggest that, in general, *Ixodes* ticks may possess physiological properties that are conducive to the growth and multiplication of Lyme disease spirochetes, while ticks in other genera may possess physiologic attributes that are less propitious, if not inhospitable, to *B. burgdorferi*.

Robert J. Keiffer

Captive black-tailed deer in Lyme disease study, September 1990

2127. Lane, Robert S., Diana M. P. Berger, Leslie E. Casher, and Willy Burgdorfer. 1994. **Experimental infection of Columbian black-tailed deer with the Lyme disease spirochete.** J. Wildl. Dis. 30(1):20-28.
Abstract: The course of *Borrelia burgdorferi* infection in Columbian black-tailed deer (*Odocoileus hemionus columbianus*), its effect on the health of these animals, and their reservoir competence for fleas were evaluated experimentally. Four yearling females inoculated intramuscularly with 10^8 organisms of the CA4 strain of *B. burgdorferi*, and two yearling males unexposed to spirochetes, were monitored daily for 3 mo. Spirochetes were reisolated from the blood of 3 does at 14 or 70 days postinjection, and from several tissues of the fourth doe at necropsy. Considerable antigenic heterogeneity was observed among the reisolates as determined by sodium dodecyl sulfate-polyacrylamide gel electrophoresis. Only 2 of the 4 infected deer developed significant antibodies (≥1:128) to *B. burgdorferi* with titers persisting for ≤2 mo. Hematological values were highly variable and the degree of variation observed was much greater than that reported previously for Columbian black-tailed deer or other subspecies of mule deer. Infected deer did not manifest signs of Lyme disease. On histologic examination of 8 tissues per deer, we observed a minimal hepatic lesion in all animals exposed to *B. burgdorferi*. No spirochetes were detected in 367 fleas (*Pulex irritans*) that had naturally infested these deer; thus this flea probably is an inefficient host of *B. burgdorferi.*

2128. Lane, Robert S., Richard N. Brown, Joseph Piesman, and Chindi A. Peavey. 1994. **Vector competence of *Ixodes pacificus* and *Dermacentor occidentalis* (Acari: Ixodidae) for various isolates of Lyme disease spirochetes.** J. Med. Entomol. 31(3): 417-424.
Abstract: The vector competence of the western black-legged tick, *Ixodes pacificus*, and the Pacific Coast tick, *Dermacentor occidentalis*, for the Lyme disease spirochete (*Borrelia burgdorferi*) was compared. Rabbits, hamsters, and the deer mouse, *Peromyscus maniculatus*, were injected with cultured spirochetes or infected tick-suspensions, or were fed upon by spirochete-infected ticks. Five of 7 isolates used as inocula were reisolated from vertebrates with the ear-punch biopsy technique. Three isolates (CA4, 5, 7) that were infectious for both vertebrates and ticks possessed prominent low-molecular-weight protein bands that had relative mobilities of ~24-26 kd. The ability of ticks to acquire and maintain various inocula of *B. burgdorferi* was evaluated by feeding uninfected larvae xenodiagnostically on all 3 hosts 0-63 days postinjection. Low percentages (0-10.6%) of the *I. pacificus* and none of the *D. occidentalis* became infected. By contrast, 33% of *I. pacificus* and 40% of *Ixodes scapularis* (= *I. dammini*) that fed on hamsters infected by tick-bite acquired and transstadially passed spirochetes; 10% of *D. occidentalis* fed on infected hamsters similarly acquired but did not maintain spirochetes. *Ixodes pacificus* nymphs efficiently transmitted *B. burgdorferi* to deer mice and a hamster. Feeding by one spirochete-infected nymph was sufficient to produce patent infections in each of 5 mice.

2129. Lane, Robert S., Joyce E. Kleinjan, and George B. Schoeler. 1995. **Diel activity of nymphal *Dermacentor occidentalis* and *Ixodes pacificus* (Acari: Ixodidae) in relation to meteorological factors and host activity periods.** J. Med. Entomol. 32(3):290-299.
Abstract: Relation of diel activity and questing behavior of nymphal *Dermacentor occidentalis* and *Ixodes pacificus* to meteorological factors was investigated in a shaded versus a sun-exposed outdoor arena. Oak-woodland soil covered partially with leaf litter and small rocks, and 24 vertically oriented grass stems 2.5, 5.0, 10.0, and 20.0 cm tall were provided as substrate and potential questing sites. Tick activity and weather conditions were monitored bihourly during 15 diel (24-h) experiments. In shade, *D. occidentalis* was active throughout the day, but questing occurred mainly at night and in the morning on grass stems or atop soil when temperatures were cool and relative humidities high. Ticks seemed to prefer to quest at heights between ~4 and 10 cm. The time of day and height at which *D. occidentalis* quested on grass stems coincided with the activity periods and size of its lagomorph and rodent hosts. Low percentages (≤15%) of *I. pacificus* nymphs were active atop soil or leaf litter at night or sporadically throughout the day, but none ascended grass stems. This finding was reconfirmed by monitoring diurnal behavior of nymphs in an outdoor aquarium having leaf litter as substrate; ≤4% of 53 ticks were detected on the topmost layer of leaves and, of those, most *I. pacificus* were situated on the lower versus the upper surfaces of such leaves. Activity of *I. pacificus* was correlated positively with relatively humidity and negatively with soil temperature in one experiment. In the sun-exposed arena, ticks of both species died within 9-11 days as daytime soil-surface temperatures sometimes reaches maximums of 73-77°C and relative humidities dropped to 14-24%. In contrast, *D. occidentalis* and *I. pacificus* survived for up to 6 and 8 weeks, respectively, in the shaded arena. After its introduction into the shaded arena, the western fence lizard (*Sceloporus occidentalis*) acquired more *I. pacificus* nocturnally while asleep in soil than during its diurnal period of activity above ground. Sleeping wild lizards also became infested more often and had significantly greater burdens of *I. pacificus* subadults, primarily larvae, than diurnally active lizards. Collectively, these findings demonstrate that *I. pacificus* subadults are capable of locating and attaching to their saurian hosts subterranealy as well as above ground.

2130. Lane, Robert S., Leslie E. Casher, Chindi A. Peavey, and Joseph Piesman. 1998. **Modified bait tube controls disease-carrying ticks and fleas.** Calif. Agric. 52(2):43-48.
Abstract: In northwestern California, the dusky-footed woodrat is a primary reservoir of Lyme disease spirochetes and an important host of 3 tick species that collectively transmit the causative agents of Lyme disease, human granulocytic ehrlichiosis, Rocky Mountain spotted fever, and tularemia. It also is infested by 2 flea species that

can transmit the agent of plague. We refined a method of applying pesticides to the host using liquid permethrin-treated bait tubes, and we found it to be highly effective for reducing populations of these ticks and fleas on woodrats in brushlands. Although permethrin products are not currently registered for this use, this approach offers a promising tool for controlling arthropod-borne diseases in the western United States.

Jack Kelly Clark

Les Casher, research assistant with Bob Lane's UC Berkeley ecologic studies, checks rodent bait-tube designed to control ticks, Orchard Pasture, April 1996

2131. Lane, Robert S., Chindi A. Peavey, Kerry A. Padgett, and Mavis Hendson. 1999. **Life history of *Ixodes (Ixodes) jellisoni* (Acari: Ixodidae) and its vector competence for *Borrelia burgdorferi* sensu lato.** J. Med. Entomol. 36(3):329-340.
Abstract: *Ixodes* (*Ixodes*) *jellisoni*, a nonhuman biting and little-known tick, is one of 4 members of the *I. ricinus* complex in the United States. A localized population of *I. jellisoni* inhabiting a grassland biotope in Mendocino County, CA, was studied from 1993 to 1997. Rodent trapping in all seasons revealed that the only host of both immature and adult *I. jellisoni* was the heteromyid rodent *Dipodomys californicus.* Field investigations suggested that *I. jellisoni* is nidicolous in habit, and laboratory findings demonstrated that it reproduces parthenogenetically. Known parthenogenetic females ($n = 4$) produced an average of 530 eggs of which 74% hatched, which was comparable to the fecundity and fertility of wild-caught females ($n = 8$). After the transstadial molt, 57 F_1 or F_2 nymphs derived from 2 wild-caught or 4 laboratory-reared, unmated females produced only females. *Ixodes jellisoni* males were not found on 112 wild-caught *D. californicus* individuals that were captured an average of 2 times. Collectively, these findings suggest that *I. jellisoni* may be obligatorily parthenogenetic. Borrelial isolates were obtained from 85% of 58 *D. californicus* and 33% of 21 *I. jellisoni* females removed from this rodent. None of the 7 infected female ticks passed borreliae ovarially to its F_1 larval progeny. Eight *D. californicus* and 5 *I. jellisoni*-derived isolates that were genetically characterized belonging to 2 restriction pattern groups of *Borrelia burgdorferi* s.l. Neither restriction pattern group has been assigned to a particular genospecies yet. After placement on naturally infected *D. californicus*, noninfected larval ticks acquired and transstadially passed spirochetes as efficiently as (group 1 borreliae) or 6 times more efficiently (group 2 borreliae) than *Ixodes pacificus*. As few as 1-4 infected *I. jellisoni* nymphs were capable of transmitting group 1 or group 2 borreliae to native *D. californicus*. We conclude that *I. jellisoni* is a competent vector of both restriction fragment groups when *D. californicus* is used as the animal model.

2132. Lane, Robert S., and John R. Anderson. 2001. **Research on animal-borne parasites and pathogens helps prevent human disease.** Calif. Agric. 55(6):13-18.
Abstract: A large body of basic and applied research conducted at the Hopland Research and Extension Center has focused on micro- or macroparasites that infest humans, domestic animals and wildlife, including viruses, bacteria, protozoans, helminths, and blood-sucking arthropods. Approximately 17 microorganisms detected at the HREC are transmitted by ticks, and of these, at least 5 cause zoonotic diseases– animal-borne diseases that can be transmitted to people. Scientists working at the HREC identified the basic transmission cycle of the Lyme disease spirochete in the far-western United States. This information now is being used to develop and implement risk-assessment and preventative strategies. This paper discusses some of the novel parasitological findings emanating from investigations of macroparasites of deer. The value of Hopland as a long-term field study site for epidemiology is emphasized.

2133. Lee, Dwayne. 1971. **The role of the mosquito, *Aedes sierrensis,* in the epizootiology of the deer body worm, *Setaria yehi*.** Ph.D. Dissertation, Univ. Calif. Berkeley. 143 pp.
Abstract: The bionomics of the western treehole mosquito, *Aedes sierrensis*, was studied at the Hopland Field Station to obtain information on the transmission and epizootiology of the deer body worm, *Setaria yehi*, in coastal black-tailed deer, *Odocoileus hemionus columbianus.* Larvae and pupae of this mosquito were found only in water-containing rot cavities of trees, with black oak and live oak providing most of the breeding sites. *Ae. sierrensis* overwintered in the area in the egg or larval stage. Emergence began in March as ambient temperatures gradually rose and continued until tree holes dried up in late May and June. Host-seeking and biting behavior of *Ae. sierrensis* appeared to be affected by host size, carbon dioxide emission, and climate. Under favorable conditions, females could be collected while trying to bite at any hour of the day. Biting activity ceased at dark. Males were attracted to hosts, around which they hovered and formed swarms. Males attempted to mate with all incoming females. Permanent mosquito collection stations were established at several elevations between 900 and 2,600 ft. Many *Ae. sierrensis* were collected at each level except where trees were absent. Monthly collections showed that in 1970, *Ae. sierrensis* adults were active from the middle of March to the last of August. Parity data indicated that most emergence occurred in April and May although large members of females were collected in June. Blood meals of engorged *Ae. sierrensis* were analyzed by the capillary-precipitin technique and indicated that these mosquitoes fed preferentially on deer. In the laboratory, this mosquito showed gonotrophic concordance. Results also indicated that temperature was a factor affecting the rate of blood meal digestion. The gonotrophic history of females, determined by studying ovariole morphology, permitted the construction of a parity profile for the wild *Ae. sierrensis* population. Most females were nulliparous in April and May and a high percentage was one or more parous in June, July, and August. Few females completed more than 4 gonotrophic cycles. Two mark-release-recapture experiments were conducted. Recapture of marked mosquitoes was significantly higher than previously reported, and the results indicated that *Ae. sierrensis* does not disperse great distances in the field. The results also indicated that this mosquito survives for considerable periods under natural conditions. A high percentage of wild-caught *Ae. sierrensis* females contained infective larvae of *Setaria yehi*. The overall natural infection rate was 7.6%, and 10% of the parous females harbored infective forms. In the laboratory, 3 species of aedine mosquitoes were infected with larval stages of *S. yehi* via a membrane feeder. The larvae molted to the 3rd stage in 10-12 days at 90°F and 12-14 days at 80°F. Unsuccessful attempts were made to establish *S. yehi* in rabbits and rats by transplanting adult worms from

deer to their peritoneal cavities. Seventy-seven deer of various ages were examined for *Setaria yehi* during 1969 and 1970; over 80% of the fawns harbored adult worms but a low percentage of older animals was infected. Three bottle-reared deer fawns were experimentally infected with *S. yehi* by allowing wild-caught female mosquitoes containing 3rd stage larvae to feed on them. The prepatent period varied from 60 to 95 days. Results suggested that only a small number of infective larvae was needed to establish a patent infection. Experimental deer were bled at various intervals during the day and results indicated that a subperiodicity could have been present.

2134. Lee, Dwayne, and Val J. Dutson. 1971. **Lung acariasis in Northern California ground squirrels.** J. Wildl. Dis. 7:57-58.
Abstract: Eight of 79 ground squirrels (*Citellus beecheyi*), collected in Mendocino County and Monterey County, were found infected with the lung mite *Pneumocoptes banksi.* In 6 animals, the total number of mites recovered ranged from 2 to 35, while over 100 mites were recovered from each of the other 2 squirrels. All infected animals were females. Histological sections examined from heavily-infected squirrels showed that the mites induced a reaction indicative of a foreign body type of bronchopneumonia, of long duration. The reaction is characterized by a heavy infiltration of granulocytes, and diminished lung function was apparent. In some sections, large areas of tissue was seen to coalesce with adjacent cyst-like formations which appeared to be mite eggs.

2135. LeFebvre, Rance B., Robert S. Lane, Guey-Chuen Perng, Julia A. Brown, and Russell C. Johnson. 1990. **DNA and protein analysis of tick-derived isolates of *Borrelia burgdorferi* from California.** J. Clin. Microbiol. 28(4):700-707.
Abstract: Nine isolates of *Borrelia burgdorferi* from ixodid ticks collected in northern California were characterized. Restriction endonuclease analysis, pulsed-field gel electrophoresis, and western blot (immunoblot) analysis were used in this study. Four isolates were very similar to each other. The others shared some similarities but were classified as having unique genotypes. A strain from an *Ixodes neotomae* tick displayed the greatest genetic and antigenic diversity when compared to the isolates collected from *Ixodes pacificus* ticks. A computerized library based on DNA banding patterns of the isolates by restriction enzyme analysis is also reported. This library was created by using a scanning laser densitometer.

2136. Leprince, D. J., and Robert S. Lane. 1996. **Evaluation of permethrin-impregnated cotton balls as potential nesting material to control ectoparasites of woodrats in California.** J. Med. Entomol. 33(3):355-360.
Abstract: The dusky-footed woodrat, *Neotoma fuscipes*, is a natural reservoir of the Lyme disease spirochete, *Borrelia burgdorferi*, in California. To investigate the potential of host-targeted insecticide to control the tick vectors of *B. burgdorferi*, permethrin-impregnated or untreated cotton balls were distributed in metal cylinders as potential nesting material adjacent to 95 woodrat houses in chaparral-covered rangeland. Laboratory experiments demonstrated that adult woodrats would enter the cylinders and construct nests from permethrin-treated or untreated cotton. The residual concentration of permethrin did not vary significantly during an 11-month period and remained >60% of the registered insecticidal formulation (7.5% AI by cotton weight). The abundance of 4 species of ticks (*Ixodes neotomae*; the western black-legged tick, *I. pacificus; I. woodi*; and the Pacific Coast tick, *Dermacentor occidentalis*) infesting woodrats was similar in the treatment and control areas. Although >90% of the cotton disappeared from the metal cylinders in both areas, examination of 8 active woodrat houses revealed that small amounts of cotton had been incorporated into the nest cups of only 25%. In contrast, the abundance of the flea *Orchopeas sexdentatus* decreased significantly in the treatment area only. Spirochetes were not detected in 168 adult *O. sexdentatus* fleas that had fed on spirochetemic woodrats, which demonstrates that this flea is an inefficient host of *B. burgdorferi*. We conclude that the use of permethrin-impregnated cotton as potential nesting material is ineffective for controlling ticks associated with the dusky-footed woodrat in brushlands, but this methodology may be useful for reducing populations of sylvatic fleas.

2137. Longhurst, William M., and James R. Douglas. 1953. **Parasite interrelationships of domestic sheep and Columbian black-tailed deer.** Trans. N. Am. Wildl. Conf. 18:168-188.
Abstract: A study of sheep- and deer-parasite interrelationships was carried out at the Hopland Field Station of the University of California College of Agriculture. Field and laboratory work extended from November 1951, through January 1953. Principal emphasis was on determining the kinds of parasites present, seasonal fluctuations in numbers and their effects on their hosts. Data were gathered from field observations, fecal examinations and autopsies of 63 sheep and 81 deer. Thirty-nine kinds of parasites were identified from sheep and deer and of these, 20 species were found common to both animals. Nematodes belonging to the genera *Ostertagia*, *Trichostrongylus*, and *Dictyocaulus* which infected the abomasums, small intestine, and lungs respectively, were considered to have the most serious effects. Parasites contributed to heavy losses among deer, and sheep were also materially debilitated but did not suffer excessive losses. Lambs were successfully infected with nematode larvae cultured from deer feces. During the winter of 1951-52 when the range was overstocked with sheep and deer, the effects of malnutrition intensified parasitism. Subsequent reduction in numbers of animals on the range helped reduce deer losses in the winter of 1952-53, even though weather conditions were more favorable for nematode infections. Chemical control of nematodes is not practical for deer, but it can be effectively applied to sheep. Such chemical control in sheep should reduce the rate of infection in deer. However, the most promising parasite controls are through improving range conditions and maintaining proper stocking rates for both sheep and deer.

2138. Longhurst, William M., James R. Douglas, and Norman F. Baker. 1954. **Parasites of sheep and deer.** Calif. Agric. 8(7):5-6.
Abstract: Similar foraging habits of sheep (*Ovis aries*) and deer (*Odocoileus hemionus columbianus*) provide ample opportunity for transference of mutual parasites. Field and autopsy data collected from sheep and deer, primarily at the Hopland Field Station, indicated that of several kinds of parasites found, roundworms infecting the abomasum, the small intestine, and the lungs had the most serious effects on the host animals. In all, 45 kinds of parasites were identified. Of these, 21 species were common to both animals: 1 protozoan, 1 fluke, 5 tapeworms, 22 roundworms, 2 lice, 6 flies, 1 flea, 5 ticks, and 2 mites. Roundworms of the genera *Ostertagia*, *Trichostrongylus*, and *Dictyocaulus* were considered to be the most important forms involved. The period of maximum nematode transference was from November until mid-April, during which both animals fed almost exclusively on grass and herbs. Deer deteriorated in condition during this period, and approximately 40% of the deer herd succumbed during the winter of 1951-52. Malnutrition coupled with multiple roundworm infections probably accounted for most of the losses among fawns. Both sheep and deer were found to build up a resistance to worms after exposure, so that animals past their first year generally carried only a small worm burden. It is apparent that sheep can handle a larger volume of forage for their size and can possibly digest it more efficiently in their longer intestinal tracts than can deer. Chemical control of nematodes can be effective in sheep, and it is probable that a reduction in nematodes in sheep flocks can be of indirect benefit to deer sharing the same rangelands in that the rate of infection would be lowered.

2139. Loye, J. E., and Robert S. Lane. 1988. **Questing behavior of *Ixodes pacificus* (Acari: Ixodidae) in relation to meteorological and seasonal factors.** J. Med. Entomol. 25(5):391-398.
Abstract: The diel questing behavior of adult *Ixodes pacificus* was examined in relation to meteorological and seasonal factors in outdoor arenas in northern California. Vertical wooden dowels 25, 50, and 75 cm high were provided as potential questing sites. Questing behavior of males and females was positively correlated with relative humidity and negatively correlated with ambient temperature and, to a lesser degree, with light and soil surface temperature. The most frequent questing posture was with the capitulum directed upward. After choosing a questing site, both sexes moved little; most movement occurred nocturnally. Male ticks exposed to direct sunlight stopped questing earlier in the day than those in the shade. Questing occurred mainly near the tips of the 25 and 50 cm dowels, averaging 24.7 cm (range, 23.6-25.0 cm; n = 81) and 47.2 cm (25.0-50.0 cm, n = 64), respectively whereas the mean questing height was not as close to the tip (mean 54.7 cm; range 27.0-75.0 cm; n = 55) on the 75-cm dowels. Females selected the 25- and 50-cm dowels as questing sites significantly more often than 75-cm dowels. The distribution of ticks of both sexes on 25- and 50-cm dowels was clumped.

2140. Manweiler, Stephen A., Robert S. Lane, and Constantine H. Tempelis. 1992. **The western fence lizard *Sceloporus occidentalis*: evidence of field exposure to *Borrelia burgdorferi* in relation to infestation by *Ixodes pacificus* (Acari: Ixodidae).** Am. J. Trop. Med. Hyg. 47(3):328-336.
Abstract: The role of the western fence lizard *Sceloporus occidentalis* in the enzootiology of the Lyme disease spirochete *Borrelia burgdorferi* was evaluated in the Hopland and Ukiah areas of Mendocino County, California. In 1989, half of the 74 lizards collected monthly from April to October at Hopland were infested by the immature western black-legged tick *Ixodes pacificus* at a mean intensity of 6.0 ticks per lizards. The prevalence of infestation of lizards by immature *I. pacificus* (36 of 73) at Ukiah was similar, but the mean intensity (12.9) was approximately twice as great. Overall, zero of 223 larvae and 2 (0.6%) of 330 nymphs from both sites were found to contain spirochetes by direct immunofluorescence. Larval and nymphal *I. pacificus* fit the negative binomial distribution in spring, and the prevalence and abundance of these stages were significantly greater in spring than in summer at both sites. Spirochetes were not visualized in thick blood films prepared for 133 lizards from both localities. Plasma antibodies against *B. burgdorferi* were detected in 7 of 10 experimentally inoculated lizards, in 5 (8%) of 63 lizards from Hopland, and in 10 (14%) of 70 lizards from Ukiah. Adult lizards had a significantly greater tick burden and seropositivity rate than juvenile lizards only at Ukiah. In 1991, efforts to detect and culture spirochetes from the blood of 21 wild-caught lizards and from the tissues of 189 associated ticks that fed xenodiagnostically on them were unsuccessful. We conclude that some lizards are exposed to spirochetes during the annual activity period of immature *I. pacificus*, but that *S. occidentalis* is much more important as a host of immature ticks than as a source of spirochetal infection for such ticks.

2141. Mariassy, A. T., Dale L. Brooks, R. Ruppanner, and Darrell E. Behymer. 1984. ***C. burnetii* infection in sheep: ultrastructural observations of the placenta (Abstract).** P. 49 *in:* Proc. IIIrd Int. Symp. on Rickettsiae and Rickettsial Diseases, Czechoslovak Soc. for Microbiol., Instit. of Virology, Slovak Acad. of Sciences, Bratislava, Czechoslovakia.
Abstract: *In vitro* studies of *Coxiella burnetii* showed compartmentalization of the agent into the phagosomes and vacuoles of the parasitized cells. Inconsistencies are encountered with regard to clinical signs, Ab titers, and shedding of organisms by the infected animals. We tested the hypothesis that if intracellular containment of the *C. burnetii* also occurs *in vivo* and if the release of organism takes place in whole, unlysed cells, then under certain conditions the host's immune system is not confronted with the antigen of the parasite. We examined 8 ewes used as controls in a vaccine study, challenged HD with 21.000 PFU (one ewe received 210.000 PFU I.P.) of *C. burnetii* in Phase I. At parturition, placental tissues were fixed and prepared for light and electron microscopy. Histological and ultrastructural examination of the placental tissues revealed a severe, necrotizing (3 animals), moderate (2 animals), mild (1 animal) focal placentitis, while 2 ewes had no significant lesions. Pathologic changes ranged from complete inflammatory response, defoliation of trophoblasts, overlayed with exudate often with calcified foci. Cells and cell ghosts containing *C. burnetii* were embedded in the exudate. The milder placentitis had but minimal inflammatory component, numerous trophoblasts of the intercotyledonary regions were distended to various degree with filamentous LCV (large cell variant) and coccoid SCV (small cell variant) forms of the agent. Their concentration varied from cell to cell. Exudate overlaying this type of lesion also contained large number of LCVs and SCVs in addition to morphologically intact cells. The mildest lesion illustrated the pathogenesis of trophoblastic cell contents replacement with parasites. Few organisms in one small vacuole in one cell, progress to even larger vacuoles in other cells until cells become completely distended with both forms of *Coxiella* organism. This type of lesion usually lacked inflammatory response and exudate. We conclude: 1) *Coxiella* organism is found in both free and cell-bound forms in the exudate of severe placentitis; 2) in less severe forms, the agent is restricted to trophoblast vacuoles and the inflammatory response in minimal or absent; 3) there is ultrastructural evidence for viable, infected trophoblasts *in situ* and free in the exudate, as well as rupturing cells containing and releasing the organism; 4) it is plausible that a carrier host with a low-grade infection may shed viable, unlysed cells containing *Coxiella* organisms with placenta at parturition, without being exposed to the antigen of the same.

2142. Mathiesen, D. A., J. H. Oliver, Jr., C. P. Kolbert, E. D. Tullson, B. J. B. Johnson, G. L. Campbell, P. D. Mitchell, K. D. Reed, S. R. Telford, III, J. F. Anderson, R. S. Lane, and D. H. Persing. 1997. **Genetic heterogeneity of *Borrelia burgdorferi* in the United States.** J. Infect. Dis. 175(1):98-107.
Abstract: To examine in detail *Borrelia burgdorferi* strain diversity in the United States, 186 isolates from human, tick, and rodent sources were analyzed from multiple distinct geographic regions of the United States and abroad. Strains were characterized by genomic macrorestriction analysis and outer surface protein A (OspA) and 23S rDNA gene sequencing followed by phylogenetic analysis. Results indicate that spirochetal isolates from the United States fall into 2 major divisions and 9 or more subdivisions; human isolates fell into 5 of these subdivisions. Greater genetic diversity was observed among *B. burgdorferi* isolates from moderate climatic regions, consistent with increased tick vector and reservoir diversity. All of the *Borrelia* isolates were reactive by OspA polymerase chain reaction except for *Borrelia hermsii* controls and several tick isolates from the Northeast, which were shown to lack the 49-kb plasmid encoding OspA. The data suggest that U.S. *B. burgdorferi* isolates demonstrate substantial genetic heterogeneity, with regional differences in spirochete populations.

2143. Mercer, David R., and John R. Anderson. 1987. **Oviposition attractants for the western treehole mosquito.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 82-83.
Abstract: Factors affecting the oviposition of the western treehole mosquito, *Aedes sierrensis*, are not well known. Females do not respond to the same sort of cues as females of other mosquito species that have more constant breeding habitats. Gravid females showed a significant preference for filtered but not autoclaved treehole water

over autoclaved treehole water, laying the majority of their eggs in the former. The data suggest that oviposition response is cued by volatile chemicals that either are heat labile or are volatilized during autoclaving. The treehole whose water proved most attractive to oviposition females was a large, litter-filled treehole in a black oak, *Quercus kelloggii*. Because this treehole retained water for a significant portion of the dry season when most other treeholes had dried, it was not possible to evaluate the relative importance of tree species, litter content, microbial activity, or treehole history as possible factors contributing to the difference in attractancy. The phenolic compound *p*-cresol, a natural decay product of paper birch, is a reported oviposition attractant for the closely related *Ae. triseriatus*. We tested it on a field population of *Ae. sierrensis* females, as well as testing the response of wild females to several other phenolic compounds found in the treehole habitats of this mosquito. To date, we have been unable to identify compounds that serve as oviposition attractants; studies are continuing.

Randy Mercer

UC Berkeley mosquito researchers check oviposition traps in oak woodland designed to attract female western treehole mosquitoes, Summer 1986

2144. Mercer, David R., and John R. Anderson. 1989. **Ovipositional attractants for *Aedes sierrensis*, the western treehole mosquito.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 70-71.
Abstract: These experiments were conducted to determine the source and identify of an oviposition cue for *Aedes sierrensis*. We tested the abilities of various developmental stages of *Ae. sierrensis* to produce compounds attractive to ovipositing females, and compared our results with those previously published. We also investigated the seasonal production of attractive compounds in order to find the source of an oviposition cue. Gravid *Ae. sierrensis* females showed a significant preference for ovipositing into larval rearing pan water, but not into larval holding water or pupal emergence water. Ovipositing females significantly preferred early season treehole water over simultaneously collected trunk-wash rain water, and they preferred lyophilized treehole water over distilled water. Data suggest that ovipositing females are selective but do not recognize compounds from immature mosquitoes in making their selection. Microbial activity may signal appropriate oviposition habitats to gravid females. Compounds associated with microbial activity are present in high concentrations in native treehole and larval rearing pan waters, but not in larval or pupal wash solutions. The fact that freezing and lyophilization do not eliminate the attractiveness of treehole water for ovipositing females is significant, since many separation techniques utilize these procedures. We will continue to investigate liquid chromatographic methods of separation.

2145. Mercer, David R., John R. Anderson, and Jan O. Washburn. 1990. **Induction of *Lambornella clarki* (Protozoa: Ciliophora: Tetrahymenidae) by *Aedes sierrensis* (Diptera: Culicidae) larvae: fine-tuned biological control of mosquitoes by a protozoan.** Pp. 182-187 *in:* Proc. Calif. Mosq. Vector Control Assoc., Vol. 57, Los Angeles, CA, Jan. 29 - Feb. 1, 1989.
Abstract: *Lambornella clarki* is a facultative parasite of the western treehole mosquito, *Aedes sierrensis*. The parasitic form of this ciliate is induced by mosquito larvae via a water-borne cue. We report the influence of larval density, larval feeding, and temperature upon the formation of this cue. These characteristics are discussed in terms of the specificity of interactions between the parasite and its host, and in terms of the biological control of container-breeding mosquitoes.

2146. Mercer, David R., and John R. Anderson. 1991. **Effects of tannin concentration on *Aedes sierrensis* development and parasitism by *Lambornella clarki*.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 60-61.
Abstract: Tannins occur naturally in oak foliage and bark and are released into treehole water during decomposition of treehole litter. Populations of *Aedes sierrensis* tolerate a range of tannin concentrations in their rearing solutions, although tannins may slow their development rates. Exposure to high pine tannin concentration resulted in the deformation and death of *Lambornella clarki.* The number of adult mosquitoes emerging from larvae reared in solutions increased with tannic acid concentration, as did the mean time to adult emergence. Tannic acid solutions did not influence adult mosquito size but did slow developmental rates of immatures at intermediate and high concentrations.

2147. Mercer, David R. 1992. **The chemical ecology of *Aedes sierrensis*, the western treehole mosquito.** Ph.D. Dissertation, Univ. Calif. Berkeley. 233 pp.
Abstract: *Aedes sierrensis* (Diptera: Culicidae) is the most abundant treehole mosquito in California, and *Lambornella clarki* (Ciliophora: Tetrahymenidae) its most important natural enemy. Populations of *L. clarki* are induced to parasitism by a larval cue which may be exploited in the biological control of *Ae. sierrensis* by *L. clarki.* Larval feeding rates and diet mediated production of the short-lived induction cue; larvae fed penicillin or nutritive substrates induced a greater parasitic response than larvae fed inert substrates or starved larvae. Induction activity was concentrated in, but not restricted to, the larval gut. Homogenates of non-host dipteran larvae induced a parasitic response, but only mosquito larvae excreted the cue into their habitat. The parasitic response of *L. clarki* populations, proportional to the concentration of induction cue, was saturated at high larval densities. Induction of *L. clarki* laboratory cultures was correlated with treehole flooding history, but not with densities of natural larval populations. Gel filtration chromatography produced a high molecular weight fraction with high induction activity. Solubility properties, heat lability and papain catalysis indicated that the cue is a dietary protein. *Lambornella clarki* exploits an induction cue directly linked to larval predation. Tannins in treehole habitats may regulate mosquito production and disease transmission. *Aedes sierrensis* populations produced adults over a wide range of tannin concentrations. Tannin concentration had limited influence upon adult size and sex ratio in laboratory and field experiments. Under field conditions, dissolved tannins slowed developmental rates of larvae, but adult eclosion tracked environmental stimuli. Tannin tolerance by laboratory cultures of *L. clarki* was restricted, relative to its host. *Lambornella clarki* of 3 geographic strains were induced to parasitism at tannin concentrations which killed most cells. The parasitic response of *L. clarki* to high concentrations of tannins may provide a refuge within *Ae. sierrensis* larvae. Tannin concentrations in natural treehole water varied with time since treehole flooding, precipitation, and evaporation. Under field conditions, tannin

concentration influenced mosquito development more than food allocation, the presence of *L. clarki*, or any combination of these variables; adult numbers, developmental rate, sex ratio, and male winglength were significantly influenced by tannin concentration in this study.

2148. Mercer, David R. 1993. **Effect of tannic acid concentrations on development of the western treehole mosquito, *Aedes sierrensis* (Diptera: Culicidae).** J. Chem. Ecol. 19:1119-1127.
Abstract: Populations of the western treehole mosquito *Aedes sierrensis* completed development in tannic acid solutions over a wide concentration range (i.e., 0-1.0 g/liter) in artificial microcosms exposed to field conditions. The most notable effects of high tannic acid concentration were to slow larval development rates and to reduce numbers of adults produced; adult size and sex ratio were minimally affected. Vector potential of this species is discussed in terms of tannin concentration.

2149. Mercer, David R., and John R. Anderson. 1994. **Tannins in treehole habitats and their effects on *Aedes sierrensis* (Diptera: Culicidae) production and parasitism by *Lambornella clarki* (Ciliophora: Tetrahymenidae).** J. Med. Entomol. 31(1):159-167.
Abstract: Tannin concentration, measured as total phenolics, varied widely in natural treehole water throughout the period of development for *Aedes sierrensis*, the western treehole mosquito. Tannic acid induced a parasitic response in free-living populations of the protozoan *Lambornella clarki*, an effect not entirely explained by acidity. Tannic acid concentration influenced mosquito developmental rates, survival, size, and proportion females more than food level, *L. clarki* parasite exposure, or any interaction of treatments for *Ae. sierrensis* populations reared in artificial microcosms exposed to natural conditions.

2150. Mercer, David R. 1996. **Correlation between colorimetric and protein-precipitation assays of tannins dissolved in treehole water.** J. Med. Entomol. 33(1):159-161.
Abstract: Tannins are polyphenolic, water-soluble, high molecular weight plant compounds that characteristically bind with proteins. Tannins may provide plant tissues with structural support or protection from pathogens and herbivores. Tannins, which are widespread among tree species colonized by treehole mosquitoes, are leached from treehole litter during decomposition. Once dissolved, the form soluble and insoluble complexes with proteins. Theoretically, tannins may affect microorganisms that provide food for mosquito larvae either directly or indirectly through their decomposition products. Thus, tannins may influence mosquito development, size, number, and interactions with natural enemies. In this study, there was a significant correlation between colorimetric and protein-precipitation assays of tannins dissolved in treehole water. The protein-precipitation potential of early-season treehole water was extremely low relative to total phenolics measured by colorimetry. The protein-precipitation method is recommended because it directly measures protein binding, the property of dissolved tannins relevant to mosquito development. Furthermore, the procedure is not affected by treehole water color and does not produce dangerous wastes.

2151. Middlekauff, Woody W. 1964. **Effect of photoperiod upon oögenesis in *Melanoplus devastator* Scudder (Orthoptera: Acrididae).** J. Kansas Entomol. Soc. 37(2):163-168.
Abstract: The grasshopper *Melanoplus devastator* is widely distributed over the lower elevation rangelands of California and the eastern portions of Oregon and Washington. It is considered one of the most important grasshopper species in California, as it feeds on rangeland forbs and grasses. During outbreak years it moves from the foothills into adjacent agricultural lands and causes great financial loss. Dissections of wild-caught females showed that oögenesis started in both collection areas (north coast drainage, Hopland, Mendocino County; and central coast drainage, Mission Peak, Alameda County) during the first week in August. Mature eggs were present in females from about the first or second week in October. Laboratory studies in walk-in cabinets with automatically controlled fluorescent lights show that the induction of oögenesis in *M. devastator* is triggered by decreasing photoperiod. One hundred females subjected to a constant short day-length period of 9½ hours over a 5-week period contained eggs in a much more advanced stage of development than did 100 females subjected to longer day lengths starting at 14 hours and decreasing in increments to 12 hours and 40 minutes when the experiment concluded 5 weeks later.

2152. Middlekauff, Woodrow W., and Robert S. Lane. 1976. **A new species of *Apatolestes* from California (Diptera: Tabanidae).** Pan-Pac. Entomol. 52(4):311-313.
Abstract: The authors describe a new species of fly, *Apatolestes rugosus* (Diptera: Tabanidae), which is most closely related to *A. willistoni.* The holotype female and allotype male were collected by J. R. Anderson at the Hopland Field Station in 1973. This brings to 11 the total number of species in this genus, 4 of which are confined to the state of California.


Robert S. Lane

Horse fly, *Tabanus* sp., feeding on a horse

2153. Middlekauff, Woodrow W., and Robert S. Lane. 1980. **Adult and immature Tabanidae (Diptera) of California.** Bull. of the Calif. Insect Survey, Vol. 22, Univ. Calif. Publications, Univ. Calif. Press, Berkeley, CA. 99 pp.
Abstract: This publication is a comprehensive review of horse flies and deer flies (Diptera: Tabanidae) in California. Included are 73 species and 7 subspecies of Tabanidae in 11 genera from the state. Genera containing the most species are *Chrysops*, *Hybomitra*, *Apatolestes*, and *Tabanus*, together accounting for 75% of all species recorded from California. Adult North American tabanids vary in size from about 6.5 to 30 mm in length. These usually stout, big-headed and big-eyed flies are found from sea level to 3,300 m or more. Tabanids frequent a great variety of habitats, ranging from deserts to alpine environments, usually with a moist or wet breeding site nearby. Most are active on warm, sunny days. Some species are rare, while other may occur in such numbers that their persistent and painful attacks make normal outdoor activities for humans, domestic livestock, and mammalian wildlife unbearable or uncomfortable. Feeding habits vary, but most females are hematophagous. Some females, as well as all males, subsist on nectar and plant exudates. Those that attack mammals tend to favor large mammals as hosts. The publication contains information on adult taxonomy and distribution, as well as on biosystematic studies of the immature

stages.

2154. Moss, Wayne W., Jr. Oliver, James H., and Bernard C. Nelson. 1968. **Karyotypes and developmental stages of *Harpyrhynchus novoplumaris* sp. n. (Acari: Cheyletoidea: Harpyrhynchidae), a parasite of North American birds.** J. Parasitol. 54(2):377-392.
Abstract: Descriptions are given of karyotypes, developmental instars, and host associations of the cheyletoid mite *Harpyrhynchus novoplumaris* sp. n. The karytopes strongly suggest the haplo-diploid method of sex determination, with $n = 2$. There is a strong possibility that the species is arrhenotokous. The developmental stages for both sexes of the mite consist of egg, larva, protonymph, deutonymph, and adult; all stages subsequent to the egg exhibit sexual dimorphism and are easily distinguishable from each other. Adult females and female deutonymphs are relatively immobile and occur at the bases of feathers, in the region of the head, neck, and breast; the other stages move freely over the skin of the host. Oviposition occurs at the base of a feather, the eggs being laid serially and enclosed in a semifibrous sheath that envelops the female as well. A brown creeper examined thoroughly for degree of infestation had 85 attached female mites; the maximum number of eggs per female was 48. Lack of success in collecting ovipositing females at seasons other than the spring suggests that the parasite's reproductive season is correlated with that of its hosts. One two separate occasions both *H. novoplumaris* and *H. brevis* were collected from the same host specimens. *H. novoplumaris* has to date been taken from the type host (the brown creeper, *Certhia familiaris*) and from 6 additional host species, representing 4 families of passeriforms; at Hopland, it was collected from a brown creeper and from a chipping sparrow, *Spizella passerina*. The adult female holotype, collected at Hopland, resides in the USNM Collection, Washington, D.C. The mite occurs across North America, from Maryland to California.

2155. Nelson, Bernard C. 1972. **A revision of the new world species of *Ricinus* (Mallophaga) occurring on Passeriformes (Aves).** Univ. Calif. Entomol. Pub. Vol. 68, Univ. Calif. Press, Berkeley, CA. 175 pp.
Abstract: Species of *Ricinus* that are ectoparasites of passerine birds in the New World are revised taxonomically in this publication. The genus occurs on members of 28 or the 70 families of passeriform birds (Passeriformes). A relict distribution is indicated. Little biological information is available for species of *Ricinus*. Rates of incidence and infestation usually are low, at least in California. Observations that are available indicate an apparent concordance in the reproductive seasons of the lice and their hosts. "Preferred" ovipositional sites are demonstrated. Hematophagia as an exclusive method of feeding is strongly suggested by piercing-sucking mouthparts and the presence of blood in the gut. An investigation of the zoonotic role of species of *Ricinus* is needed. A historical review of the extreme confusion that has surrounded the status of the name *Ricinus* and that of its type species *R. fringillae* is presented. Their status is now fixed and accepted, as noted. The external morphology of the species *Ricinus* is described, with emphasis on the salient features used in defining and recognizing the species. A system of chaetotaxy is erected. Measurements of various structures are of little use in defining species because of presence of much intraspecific variation and apparent host-induced variation. Characters found to have diagnostic value are the shape of structures, the pigmentation pattern, and the chaetotaxy. A species is defined on the basis of multiple characters. A hypothetical phylogeny is proposed for the genus *Ricinus* and its species, based upon modifications of several structures found on extant forms. Changes in the structure of the labium, labrum, mandibles, tentorium, and thorax among others demonstrate that *Ricinus* is a specialized genus in the suborder Amblycera. Specializations exhibited within the genus indicate that *Ricinus* had undergone two separate radiations, interspersed by a period of decline. The genus is re-described and divided into 8 species groups, with 38 species considered valid. Twenty-five specific and sub-specific names are judged synonyms. Five names are designated *species inquirendae*. *R. nigrolimbatus* is designated *nomen dubium*. Twenty-four species are re-described, of which 4 are given *sensu lato* status. Fourteen new species are described. Certain species of *Ricinus* show host specificity at the specific, generic, and family level. Certain species group show host specificity at the family, superfamily, or subordinal level. These forms are found useful in deducing probably host phylogeny. Other species and species groups are distributed so anomalously that no correlation is apparent between the evolution of the lice and their hosts. It is proposed that secondary transfers have occurred, obscuring any phylogenetic relationship. The potential for and occurrence of secondary transfer are discussed and shown to be more common than previously realized. A seemingly anomalous distribution of a louse on two or more species of host probably indicates an ecological relationship for the hosts involved. Several cases are resolved in which two, and rarely, three species of *Ricinus* regularly occur on the same host species. This synoxenic distribution follows no geographical or taxonomic pattern.

2156. Norris, Douglas E., J. S. H. Klompen, James E. Keirans, Robert S. Lane, Joseph Piesman, and William C. Black IV. 1997. **Taxonomic status of *Ixodes neotomae* and *I. spinipalpis* (Acari: Ixodidae) based on mitochondrial DNA evidence.** J. Med. Entomol. 34(6):696-703.
Abstract: *Ixodes spinipalpis* and *I. neotomae* are enzootic vectors of *Borrelia burgdorferi* in western North America. The taxa overlap in host preference, habitat, and morphology. Mitochondrial DNA was compared between the taxa to test for reproductive isolation. A 300-bp region of the mitochondrial 16S ribosomal DNA gene was amplified in 28 specimens of *I. neotomae* and 149 specimens of *I. spinipalpis*. These products were screened for sequence variation using single-strand conformation polymorphism analysis, and 9 haplotypes were detected. Haplotype frequencies varied between taxa; however, Shannon diversity analysis indicated that most variation arose among collections within each taxon, and no unique haplotypes characterized either one. Phylogenetic analysis of 18 sequences, representing a replicate of each of the 9 haplotypes, was performed with *I. pacificus* and *I. jellisoni* as outgroups. Strong monophyletic support was found for a clade containing *I. neotomae* and *I. spinipalpis* and within this clade no lineages comprised exclusively either taxon. These results argue against treatment of *I. neotomae* and *I. spinipalpis* as distinct species.

2157. Norton, Andrew P., Jan O. Washburn, and Esther M. Omi. 1992. **Axenic culture of *Lambornella clarki* (Ciliophora: Tetrahymenidae), an endoparasite of *Aedes sierrensis* (Diptera: Culicidae).** J. Invert. Pathol. 60:164-170.
Abstract: *Lambornella clarki* is a facultative parasite of the western treehole mosquito *Aedes sierrensis*. In response to waterborne substances produced by larval mosquitoes, free-living trophonts of *L. clarki* are induced to form parasitic theronts that attach to and infect the larvae. Reported here are methods for establishing and maintaining axenic and monoxenic trophont cultures, determining cell growth rates, and inducing theront formation of *L. clarki*. Results from laboratory experiments indicate that these methods provide for reliable cell growth and induction of theronts. After 19 months in continuous axenic culture, theront formation by trophonts exposed to ground *A. sierrensis* larvae declined, while moderate levels of theronts (16%) were still obtainable from trophonts exposed to water previously containing larvae. Highest cell densities and theront production were achieved from trophonts cultured in media that also contained *Streptomyces* spp.

2158. Oliver, J. H., and B. C. Nelson. 1967. **Mite chromosomes: an exceptionally small number.** Nature 214(5090):809.
Abstract: While chromosomes of thousands of plants and animals have been investigated and chromosome numbers found to vary widely, the overall trend has been toward the evolution of a moderate number in most taxa. Very few species have been reported to have as few as $n = 2$ chromosomes. In this paper, mites (*Harpyrhynchus* spp.) and their eggs were collected from chipping sparrows (*Spizella passerina*) at the Hopland Field Station. Many embryos and hundreds of cells were analyzed and all were found to have were found to have 2 or 4 chromosomes in a cell, but only one type to each embryo. It is undetermined, at present, whether these chromosomes are monocentraic or holocentric. *Harpyrhynchus brevis* and a second species of *Harpyrhynchus* were collected; we saw no differences in chromosome number, morphology, or size between the two species, but they are readily distinguished by external morphological criteria. Haplo-diploidy is common in many mite families and is the dominant sex determining mechanism in one family included in the same sub-order as this genus. The co-existence of haploid and diploid embryos, however, does not in itself prove arrhenotoky, although it is probable.

2159. Olkowski, W., John R. Anderson, and J. B. Hoy. 1967. **Relationships between host attack rates and CO_2-baited malaise trap catches of certain tabanid species (Abstract).** Pp. 77-78 *in:* Proc. Calif. Mosq. Vector Control Assoc., Vol. 35, San Francisco, CA, Feb. 5-8.
Abstract: CO_2-baited Malaise traps (*see* Anderson and Olkowski 1967) captured 1,100 specimens of 14 species of Tabanidae from May 27 to June 15, 1966. All trapping was conducted at the University of California Hopland Field Station, located in the foothills of the Russian River Valley in Mendocino County. Trap catches were collected at 1100, 1400 and 1700 each day, and hourly weather data were obtained from the nearest field station weather station. Seventy-eight percent of the total trap catches were composed of four species: *Silvius notatus*, *Tabanus similis*, *T. kesseli*, and *Apatolestes comastes* (in decreasing order). Air temperatures greatly influenced the numbers of flies caught in traps. The minimum host seeking activity threshold was approximately 70°F, whereas 80-89°F appeared to be the optimum host seeking temperature range for all but a few species. CO_2-baited Malaise traps caught significantly greater numbers of flies than unbaited traps. Unlike the results for the *Symphoromyia* species, many more tabanids were captured in the CO_2-baited traps than were observed on deer. Trap catches therefore revealed that more tabanids were present in the area than indicated by the numbers feeding on deer. These results suggest that the tabanids are less host specific than the *Symphoromyia* species captured, and that CO_2-baited traps may be more efficient in capturing hematophagous tabanids than in catching similar rhagionids. However, further studies are needed before such suggestions can be advanced as conclusions.

2160. Osebold, John W., John F. Christensen, William M. Longhurst, and Merton N. Rosen. 1959. **Latent *Anaplasma marginale* infection in wild deer demonstrated by calf inoculation.** Cornell Vet. 49(1):97-115.
Abstract: Results of inoculations into calves and fawns of blood obtained from wild deer in two areas of the coastal mountain area of California are described. Ten of the 14 calves (13 splenectomized) inoculated with pooled or individual samples of blood collected from 41 trapped deer in Mendocino County developed anaplasmosis. Seven of 8 splenectomized calves inoculated with pooled or individual samples of blood collected from 23 deer in San Benito County developed the disease. Strains of *Anaplasma* isolated from deer were transferred readily by blood inoculation from deer to calf, from calf to calf, from calf to deer, and from deer to deer. On the basis of the susceptibility of the bovine host, pattern of the disease process, morphology and staining characteristics of the anaplasma bodies, and serological specificity as determined by *A. marginale* antigen, these strains isolated from deer were considered to be *A. marginale*. Deer may constitute an important reservoir of infection for anaplasmosis, a fact which would complicate efforts toward control of the disease in range areas occupied by both deer and cattle.


Robert S. Lane

A questing western black-legged tick, *Ixodes pacificus*, waits on vegetation for an appropriate warm-blooded host to pass

2161. Padgett, Kerry A., and Robert S. Lane. 2001. **Life cycle of *Ixodes pacificus* (Acari: Ixodidae): timing of developmental processes under field and laboratory conditions.** J. Med. Entomol. 38(5):684-693.
Abstract: The developmental timing of *Ixodes pacificus*, the primary vector of the Lyme disease spirochete and the agent of human granulocytic ehrlichiosis in the far-western United States, was determined under field and laboratory conditions. During their seasonal peaks of abundance, each of the three parasitic stages of *I. pacificus*, both fed and unfed, was placed inside silk-screen packets. These packets were apportioned between four topographic exposures of two hilltop sites in northwestern California. The sites differed in vegetational composition and elevation: the first (elevation 390 m) was dominated by woodland-grass, the second (elevation 914 m) by chaparral. The timing of oviposition, larval eclosion, molting, and mortality were recorded in the field every 2-3 weeks for 2.5 years. Microenvironmental temperatures were measured on all four exposures at both sites. Accelerated developmental rates of all three stages were correlated with warmer soil temperatures and the time of placement in the field. In the laboratory, replete female *I. pacificus* maintained under uniform environmental conditions sustained constant preovipositional and pre-hatch periods independent of date-of-feeding. In the field, all unfed stages survived through one summer and early spring. No life stage survived through two active feeding periods, which suggests that cohorts do not overlap. We concluded that *I. pacificus* takes a minimum of 3 years to complete its life cycle in northwestern California.

2162. Peavey, Chindi A., and Robert S. Lane. 1996. **Comparison of infectivities of six tick-derived isolates of *Borrelia burgdorferi* for rodents and ticks.** J. Clin. Microbiol. 34(1):71-75.
Abstract: The infectivity and dissemination to the skin of 6 isolates of *Borrelia burgdorferi* were evaluated by inoculating them into groups of deer mice (*Peromyscus maniculatus*), hamsters, and Swiss Webster mice. Rodent infection was assayed by culture of ear punch biopsy specimens taken at 4, 8, and 12 weeks postinoculation (p.i.). Spirochetes were detected in biopsy specimens from individuals of all 3 host species that had been inoculated with 4 isolates (CA3, CA4, CA7, and CA8). Ear punch biopsy specimens taken from Swiss

Webster mice at 12 weeks p.i. yielded an additional reisolate (CA2), even though these animals did not seroconvert. The remaining isolate (CA9) was not recovered from any host. However, 2 deer mice and all hamsters and Swiss Webster mice inoculated with CA9 seroconverted. All 6 isolates were of low infectivity to ticks when inoculated intramuscularly into hosts. Only 4 (1.6%) of 250 *Ixodes pacificus* larvae acquired and transstadially maintained infection from hosts inoculated intramuscularly. Infectivity of 3 isolates for ticks also was tested in Swiss Webster mice injected intradermally. The mean prevalences of infection in xenodiagnostic ticks fed on these mice at 4 weeks p.i. were 47.9, 1.2, and 2.2% for isolates CA4, CA7, and CA8, respectively. The mean prevalences of infection for ticks fed on the same juice at 12 weeks p.i. were 36.4, 11.8, and 20.4%, respectively. Such differences in the infectivity and rate of dissemination of individual isolates of *B. burgdorferi* should be considered during studies of reservoir and vector competence.

2163. Perkins, Susan L., Sarah M. Osgood, and Jos. J. Schall. 1998. **Use of PCR for detection of subpatent infections of lizard malaria: implications for epizootiology.** Molecular Ecol. 7(11):1587-1590.
Abstract: The estimated prevalence of a malaria parasite, *Plasmodium mexicanum*, of western fence lizards, *Sceloporus occidentalis*, was compared using 2 techniques: microscopic examination of blood smears, and nested polymerase chair reaction (PCR) amplification of the 18S small subunit rRNA gene. Two sites at the Hopland Field Station were investigated, one with known long-term high prevalence of the parasite (30% by blood smear scanning), and one with low prevalence (6%). The nested PCR readily detected very low-level infections (<1 parasite per 10,000 erythrocytes); such infections are often subpatent by normal microscopic examination. False negatives (scored as not infected after scanning the blood smear, but found infected via PCR) were rare at both sites (4% at the high-prevalence site, 6% at the low prevalence site). However, a greater proportion of infections was detected only by PCR at the low-prevalence site (50% vs. 9%). If 50% of the infections sustain very weak parasitaemia where lizards are rarely infected, this would accord with hypotheses that predict that parasites should reduce infection growth when transmission is uncommon. The study demonstrates that PCR is a powerful tool to detect very low-level malarial infections in vertebrate hosts, including those with nucleated erythrocytes.

2164. Philip, Robert N., Robert S. Lane, and Elizabeth A. Casper. 1981. **Serotypes of tick-borne spotted fever group rickettsiae from western California.** Am. J. Trop. Med. Hyg. 30(3):722-727.
Abstract: A rickettsial survey of ixodid ticks known to bite man was conducted in 1979 in 4 coastal counties of California to obtain isolates from tick species that might be involved in the transmission of spotted fever-like illnesses, and to examine serologic characteristics of the rickettsiae relative to defined members of the spotted fever group (SFG). One hundred seventy (19.4%) of the 877 ticks comprising 3 species were shown by hemolymph test to harbor rickettsiae-like organisms. A total of 85 SFG rickettsial isolates was obtained by Vero cell culture; 83 were from *Dermacentor occidentalis*, 2 were from *D. variabilis*, and 1 was from *Ixodes pacificus*. As determined by microimmunofluorescence, the isolates comprised 4 distinct serotypes. Two serotypes were obtained only from *D. occidentalis*, and 1 each only from *D. variabilis* and *I. pacificus*, respectively. Most *D. occidentalis* isolates possessed the serologic characteristics of *Rickettsia rhipicephali*, but 3 were similar to, yet distinguishable from, *R. rickettsi* and are members of an unclassified serotype referred to as 364D. The 2 isolates for *D. variabilis* resembled the unclassified 369C serotype previously shown to be associated with this species and *D. andersoni* elsewhere in the United States. The *I. pacificus* isolate was similar to strains of the unclassified Tillamook serotype isolated from this tick in several localities in western Oregon. Representative strains of the 4 serotypes could also be distinguished on the basis of pathogenicity for Vero cells, chick embryos, guinea pigs, and/or meadow voles. The significance of these findings relative to occurrence of tick-associated illnesses in western California is briefly discussed.

2165. Philip, Robert N., Elizabeth A. Casper, Robert L. Anaker, Marius G. Peacock, Stanley F. Hayes, and Robert S. Lane. 1982. **Identification of an isolate of *Rickettsia canada* from California.** Am. J. Trop. Med. Hyg. 31(6):1216-1221.
Abstract: A strain of *Rickettsia canada* was recovered in 1980 from an adult rabbit tick, *Haemaphysalis leporispalustris*, taken from a black-tailed jackrabbit, *Lepus californicus*, in Mendocino County, California. In all examined biologic characteristics, this isolate, CA 410, is indistinguishable from the prototype, strain 2678, isolated in Ontario, Canada, in 1963. These similarities include serologic and immunologic reactivity in laboratory mice and guinea pigs, cultural characteristics in Vero cells, chick embryo cells and embryonated eggs, low pathogenicity for mice, meadow voles, and guinea pigs, unusual resistance to streptomycin, morphology by electron microscopy, and molar percentages of guanine plus cytosine of the deoxyribonucleic acids. Recovery of this second strain on the same species of tick, but far removed in time and place from the origin of the prototype, provides evidence that *R. canada* is an established, ecologically stable, rickettsia in North America. Prior to this isolation, there had been no other successful attempts to isolate this rickettsia since its original discovery in 1963. The original isolation showed this to be a distinct species, but it shares group-reactive antigen(s) with typhus rickettsiae.

2166. Poinar Jr., George O., Robert S. Lane, and G. M. Thomas. 1976. **Biology and redescription of *Pheromermis pachysoma* (v. Linstow) n. gen., n. comb. (Nematoda: Mermithidae), a parasite of yellowjackets (Hymenoptera: Vespidae).** Nematologica 22:360-370.
Abstract: *Pheromermis pachysoma* n. gen, n. comb., a parasite of the yellowjacket, *Vespula pensylvanica*, is described from California. The genus *Pheromermis* is characterized by the presence of 4 submedian cephalic papillae; large anteriorly placed cup shaped amphids; an S-shaped vagina not bent in transverse plain to the body; 6 hypodermal cords; paired short separate spicules; cuticle with cross fibers; and eggs lacking processes. The development of *P. pachysoma* is unique because a paratenic or transport host is required for completion of the life cycle. The adult nematodes occur in water or saturated soil and the eggs are fully embryonated at oviposition. The eggs hatch in the gut of various insects and infective stage juveniles penetrate the gut wall and enter a quiescent state in the tissues of these paratenic hosts. Wasp larvae are probably infected when they are fed paratenic hosts captured by worker yellowjackets. Postparasitic juveniles of *P. pachysoma* emerge from adult wasps when the latter visit wet sites after their fall emergence from the nest. The ant parasite, *Mermis myrmecophila*, is transferred to the genus *Pheromermis*.

2167. Postic, D., N. Marti-Ras, Robert S. Lane, M. Hendson, and G. Baranton. 1998. **Expanded diversity among Californian *Borrelia* isolates and description of *Borrelia bissettii* sp. nov. (formerly *Borrelia* group DN127).** J. Clin. Microbiol. 36(12):3497-3504.
Abstract: Up to now, the only species in the complex *Borrelia burgdorferi* sensu lato known to cause Lyme borreliosis in the United States has been *B. burgdorferi* sensu stricto. However, some atypical strains closely related to the previously designated genomic group DN127 have been isolated in the United States, mostly in California. To explore the diversity of *B. burgdorferi* sensu lato group DN127, we analyzed the nucleotide sequences of the rrf-rrl intergenic spacer regions from 19 atypical strains (18 from California and one from New York) and 13 North American *B. burgdorferi* sensu stricto

strains (6 from California). The spacer region sequences from the entire *B. burgdorferi* sensu lato complex available in data banks were used for comparison. Phylogenetic analysis of sequences shows that the main species of the *B. burgdorferi* sensu lato complex (*B. afzelii, B. garinii, B. andersonii, B. japonica, B. burgdorferi* sensu stricto, *B. valaisiana*, and *B. lusitaniae*) each form a coherent cluster. A heterogeneous group comprising strains belonging to the previously designated group DN127 clustered separately from *B. burgdorferi* sensu stricto. Within this cluster, the deep branches expressing the distances between the rrf-rrl sequences reflect a high level of divergence. This unexpected diversity contrasts with the monomorphism exhibited by *B. burgdorferi* sensu stricto. To clarify the taxonomic status of this highly heterogeneous group, analysis of the rrs sequences of selected strains chosen from deeply separated branches was performed. The results show that these strains significantly diverge at a level that is compatible with several distinct genomic groups. We conclude that the taxonomy and phylogeny of North American *B. burgdorferi* sensu lato should be reevaluated. For now, we propose that the genomic group DN127 should be referred to as a new species, *B. bissettii* sp. nov., and that other related but distinct strains, which require further characterization, be referred to as *Borrelia* spp.

2168. Postic, D., N. M. Ras, Robert S. Lane, P.-F. Humair, M. M. Wittenbrink, and G. Baranton. 1999. **Common ancestry of *Borrelia burgdorferi* sensu lato strains from North America and Europe.** J. Clin. Microbiol. 37(9):3010-3012.
Abstract: Ten atypical European *Borrelia burgdorferi* sensu lato (*Borrelia* spp.) strains were genetically characterized, and the diversity was compared to that encountered among related *Borrelia* spp. from North America. Phylogenetic analyses of a limited region of the genome and of the whole genome extend existing knowledge about borrelial diversity reported earlier in Europe and the U.S. Our results accord with the evidence that North American and European strains may have a common ancestry.

2169. Resh, V. H., T. S. Flynn, G. A. Lamberti, E. P. McElravy, K. L. Soeg, and J. R. Wood. 1981. **Responses of the sericostomatid caddisfly *Gumaga nigricula* to environmental disruption.** Pp. 311-318 *in:* Proc. IIIrd Int. Symp. on Trichoptera, (G. P. Moretti, ed.), Series Entomologica Vol. 20, Dr. W. Junk Publishers, The Hague.
Abstract: Life history features of the sericostomatid caddisfly *Gumaga nigricula* are described and include: a firm gelatinous egg mass that has a 'figure-8' outline; laboratory-reared larvae that molt as many as 14 times; field-collected larvae whose instars cannot be distinguished by head capsule measurements; pupae that are aggregated along stream margins; and adults, larvae, and pupae that serve as paratenic hosts of a merminthid nematode. Density of larvae and pupae in a northern California spring seepage at Hopland was 157.6 ± 78.9 individuals/158 cm^2, or ~10,000/m^2. Following severe drought and complete loss of habitat, *G. nigricula* age structure in the spring changed from that of a multiple cohort population to that of a single cohort population. Population densities and faunal dominance

of *G. nigricula* in a stream habitat (Big Sulphur Creek, The Geysers, CA) were higher following drought conditions (which resulted in reduced flow but not complete habitat loss) than following years of normal and above-normal precipitation. A recolonization study in Big Sulphur Creek indicated that hyporheic and upstream movements are more important in habitat recolonization than drift or aerial oviposition. In a long-term geothermal energy development area (The Geysers, CA), numbers of macroinvertebrate species decrease with the addition of thermal, silt, and chemical contaminants, but both density and faunal dominance of *G. nigricula* increase along this gradient. Although *G. nigricula* exhibits considerable potential for use as an indicator of water quality, taxonomic and biometric considerations require further clarification.

2170. Resh, Vincent H. 1982. **Age structure alteration in a caddisfly population after habitat loss and recovery.** Oikos 38:280-284.
***Abstract*:** Monthly collections (1975-76) from a sericostomatid caddisfly, *Gumaga nigricula*, population in a Northern California spring seepage indicated that age structure was numerically dominated by early larval instars (55-82% each month) but pupae (<1-6%) were also present year-round. Severe drought in 1977 resulted in cessation of the normally permanent spring flow and total habitat loss occurred for over 3 months; no *G. nigricula* apparently survived. Two years after habitat recovery (1979), a single cohort population with a clear temporal succession in age class dominance from early to late larval instars was evident. Temporally restricted aerial recolonization of *G. nigricula* adults from a non-drought affected habitat most likely produced the shift to a single cohort population which has persisted through 2 generations (i.e., 2 years).

2171. Resh, Vincent H. 1983. **Spatial differences in the distribution of benthic macroinvertebrates along a springbrook.** Aquatic Insects 5(4):193-200.
Abstract: Benthic samples (n=54) were collected at 3 sites along an unshaded, first-order springbrook, 0-3 m, 15-19 m, and 24-27 m below a permanent spring outflow in Mendocino County, California. As distance from spring source increased, number of species and species diversity (H) decreased, but number of individuals increased. These patterns may have resulted from temperature fluctuation regimes at these 3 sites, or from a spring source/springbrook ecotone effect. The sericostomatid caddisfly, *Gumaga nigricula*, had highest population density ($\bar{x}$ >10,000/m^2) although 7 other populations had mean densities of >100/m^2. Distribution of *G. nigricula* in the springbrook appears to reflect adult oviposition behavior. Zonation patterns and sampling variability in springbrook habitats must be considered in studies that compare first-order with higher-order streams (e.g. the River Continuum Concept).

2172. Resh, Vincent H. 1992. **Year-to-year changes in the age structure of a caddisfly population following loss and recovery of a springbrook habitat.** Ecography 15:314-317.
Abstract: A severe drought in 1977 resulted in cessation of normally permanent flow in a northern California springbrook, and no individuals of the numerically dominant macroinvertebrate, the caddisfly *Gumaga nigricula*, survived. Prior to habitat loss (1976) this population was multiple cohort; 2 years after habitat recovery (1979) a single-cohort population was present. The shift in age structure back to pre-drought conditions occurred gradually: median head capsule width in 1976 (pre-drought): 0.39 mm; 1981 (post-drought): 0.95 mm; 1982: 0.99 mm; 1983: 0.59 mm; 1984: 0.63 mm; 1985: 0.63 mm; 1986: 0.45 mm. Age structure from 1981-1985 was significantly different ($p < 0.001$) from that occurring before habitat loss in 1976; age structure in 1986 was not significantly different from that in 1976. The 10-year time for return to the original population age structure could be influenced by the isolation of the springbrook from other colonization sources, gradual increases in population density, and differential growth reflecting food availability.

2173. Ressel, S., and Jos. J. Schall. 1989. **Parasites and showy males: malarial infection and color variation in fence lizards.** Oecologia 78:158-164.
Abstract: Other researchers proposed that the quality of male showy traits reflects genetically-based resistance to parasites and can be used by females to select mates that are less prone to parasitic attack. The hypothesis requires that a particular state of a variable showy trait should be associated with parasite infection. We tested this idea with a population of western fence lizards, *Sceloporus occidentalis*, infected with the malarial parasite *Plasmodium mexicanum*. Ventral

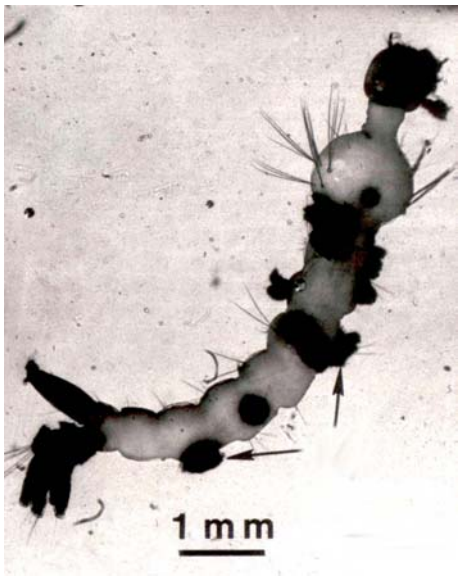
color pattern is strongly dimorphic in fence lizards and varies greatly among males in this population. Malaria-infected males exhibited significantly more black and less pale on their ventral surface than did non-infected lizards of similar body size. This difference was not a function of differing ages of infected and noninfected animals of the same body size. However, logistic regression demonstrated that females using male ventral color as a gauge of infection status would only marginally improve their chance of choosing a noninfected lizard over random selection of males.

2174. Ruppanner, Roger, Dale L. Brooks, Darrell E. Behymer, and A. T. Mariassy. 1984. ***Coxiella burnetii* infection in ewes: effects of vaccination on shedding in exposed animals (Abstract).** *In:* III[rd] Int. Symp. on Rickettsial Diseases, Czechoslovak Soc. for Microbiol., Instit. of Virology, Slovak Acad. of Sciences, Bratislava, Czechoslovakia, Sept. 10-14.
Abstract: Lambs were vaccinated with two *C. burnetii* vaccines. Antibody titers were monitored. Shedding of the organism in vaccinated animals was compared with that in nonvaccinated control animals at lambing both after natural exposure to the agent and after experimental challenge with *C. burnetii*. Two groups of ewes were similarly vaccinated; antibody titers of vaccinated and control ewes were followed for several months. Some of the ewes were subjected to natural exposure to *C. burnetii* in Phase I. Subsequently, the organism was detected in the placenta of all 6 control ewes but in only 1 of 6 and 1 of 5 vaccinated ewes. *C. burnetii* was also detected in the colostrum of 3 control ewes but in none of the vaccinated ewes.

2175. Ruppanner, Roger, Dale L. Brooks, Darrell E. Behymer, and Richard W. Ermel. 1985. ***C. burnetii* infection in ewes: will vaccination prevent shedding in exposed animals?** Pp. 85-88 *in:* Proc. 8[th] International Council for Laboratory Animal Science (ICLAS)/ Canadian Association for Laboratory Animal Science (CALAS) Symp., Gustav Fischer Berlag, Stuttgart, Vancouver, B.C., Canada. 1983.
Abstract: Lambs were vaccinated with two *Coxiella burnetii* vaccines and antibody titers were monitored. Shedding of the organisms in vaccinated animals were compared with those in nonvaccinated control animals at lambing, after natural exposure to the agent and after experimental challenge with *C. burnetii*. Two groups of ewes were similarly vaccinated; antibody titers of vaccinated and control ewes were followed for several months. Some of the ewes were subjected to natural exposure to *C. burnetii* and some were experimentally challenged with 10,000 PFU of *C. burnetii* in Phase I. Subsequently the organism was detected in the placenta of all 6 control ewes but in only 1 of 6 and 1 of 5 vaccinated ewes. *C. burnetii* was also detected in the colostrum of 3 control ewes but not in vaccinated ewes.

2176. Sacks, Benjamin N. 1998. **Increasing prevalence of canine heartworm in coyotes from California.** J. Wildl Dis. 34(2):386-389.
Abstract: Thirty-seven subadult and adult coyotes (*Canis latrans*), collected August 1992 through December 1996 from a coastal foothill area in northern California, were examined for adult heartworm (*Dirofilaria immitis*). During 1992 through 1993, at the end of a 6-year drought, none of four coyotes examined were infected with heartworms. However, during 1994 through 1996, after the drought had ended, prevalences were 91% in 23 adult coyotes and 40% in 10 subadult coyotes. Heartworm intensity did not differ by sex of coyote, and averaged (±SE) 19.4 ± 3.8 among adults; one subadult had >238 heartworms. The prevalence and intensity of heartworm infection in coyotes reported here for 1994 through 1996 are the highest reported anywhere in the United States.

2177. Sacks, Benjamin N., and Karen M. Blejwas. 2000. **Effects of canine heartworm (*Dirofilaria immitis*) on body condition and activity of free-ranging coyotes (*Canis latrans*).** Can. J. Zool. 78:1042-1051.
Abstract: We used radiotelemetry to study relationships among canine heartworm (*Dirofilaria immitis*) infection, body condition, and activity of free-ranging coyotes (*Canis latrans*). Average body mass at death was lower for 17 coyotes in a high-intensity infected group ($\bar{x}$ = 33.6 heartworms) than for 18 coyotes in a control group ($\bar{x}$ = 3.6 heartworms; $P < 0.01$). Coyotes in the infected group lost body mass at an average rate of 20% per year relative to the control group ($P < 0.01$). Bone marrow fat was negatively correlated with heartworm burden ($R^2 = 0.27$; $P < 0.01$). Average body mass of coyotes at initial capture (i.e., potentially before infection) did not differ between infected and control groups ($P = 0.90$; $1\text{-}\beta = 0.70$). Activity was negatively correlated with heartworm burden during the last 2 months of life ($R^2 = 0.30$; $P < 0.01$), but no correlation was found 2 - 4 months before death. Activity of the infected group (n = 13) declined over time ($P = 0.01$), whereas no difference in activity was observed in the control group ($n = 13$; $P = 0.50$). Our findings indicated that heartworm infection reduced body condition and activity of coyotes but that nutritional status did not significantly affect susceptibility to infection.



Dead third-instar larva of the western treehole mosquito, killed by an infection of the fungus *Pythium flevoense* (arrows indicate fungal colonies)

2178. Saunders, Gary A., Jan O. Washburn, David E. Egerter, and John R. Anderson. 1988. **Pathogenicity of fungi isolated from field-collected larvae of the western treehole mosquito, *Aedes sierrensis* (Diptera: Culicidae).** J. Invert. Pathol. 52:360-363.
Abstract: In a search for potential biological control agents for container-breeding mosquitoes, we collected and maintained larvae of the western treehole mosquito, *Aedes sierrensis*, from 69 treeholes in various geographic areas of California. Dead and moribund larvae were removed from cultures and examined. Fungi isolated from these mosquito larvae included *Geotrichum klebahnii, Fusarium oxysporum, Tolypocladium cylindrosporum, Sesquicillium candelabrum, Pythium flevoense, Saprolegnia ferax,* and *Saprolegnia* sp. *T. cylindrosporum* was the only potent parasite; the remaining fungi associated with dead or moribund *Ae. sierrensis* larvae were either opportunists or saprophytes. Opportunists were pathogenic to mosquitoes only under special circumstances (e.g. damaged host cuticle) and are normally saprophytic. Saprophytic fungi and bacteria are common in treeholes on decaying organic matter such as leaves and dead insects, and they form the base of the food web

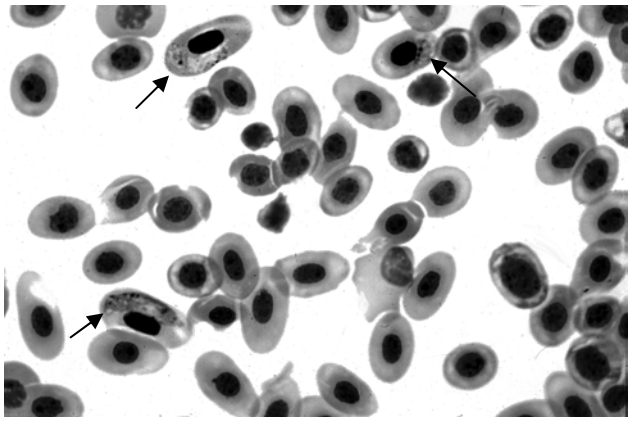
associated with these aquatic habitats. With the exception of *T. cylindrosporum*, under natural conditions, the fungi examined here probably play a minor role in the population dynamics of *Ae. sierrensis* and show little promise as biological control agents.

2179. Schall, Jos. J., Albert F. Bennett, and Robert W. Putman. 1982. **Lizards infected with malaria: physiological and behavioral consequences.** Science 217:1057-1059.
Abstract: In Northern California, western fence lizards, *Sceloporus occidentalis*, are frequently parasitized by *Plasmodium mexicanum*, which causes malaria. Animals with this naturally occurring malarial infection are anemic; immature erythrocytes in peripheral blood become abundant (1 to 30%), and blood hemoglobin concentration decreases 25%. Maximum oxygen consumption decreases 15% and aerobic scope drops 29% in infected lizards; both correlate with blood hemoglobin concentration. Running stamina, but not burst running speed, is reduced in malaria lizards. There is a hierarchical relation between infection with malaria and effects on hematology, physiological function, and behavioral capacity. The results suggest that malarial infection may have significant effects on the ecology of the lizard hosts.

2180. Schall, Jos. J. 1983. **Lizard malaria: cost to vertebrate host's reproductive success.** Parasitol. 87:1-6.
Abstract: *Plasmodium mexicanum* is a common malarial parasite of the western fence lizard, *Sceloporus occidentalis*, in northern California. Infected female lizards store substantially less fat during the summer activity season and produce smaller clutches of eggs than do non-infected animals. Stored fat is utilized in the production of eggs; the energy content of the decrement in stored fat is approximately equal to the energy content of the average reduction of number of eggs. Thus, there is ongoing strong selective pressure on the host to evolve appropriate anti-parasite measures.

2181. Schall, Jos. J. 1983. **Lizard malaria: parasite-host ecology.** Pp. 84-100 *in:* R. B. Huey, E. R. Pianka, and T. W. Schoener (eds.), Lizard Ecology: Studies on a Model Organism. Harvard Univ. Press, Cambridge, MA.
Abstract: The ecology of malaria in fence lizards was examined at a site in northern California (Hopland Field Station). Male lizards were more often infected and prevalence of the parasite varied among the 3 years (1978-1980) of the study, although this difference was not significant. Percent of lizards infected increases with lizard size, suggesting lizards maintain an infection perhaps for the duration of their life once exposed. Infected lizards had more immature red blood cells, but the number of immature cells was not correlated with parasite load. Thus, changes in the blood picture of infected lizards occur even in weak infections. Blood hemoglobin concentration drops about 25% in infected lizards. Oxygen consumption of resting lizards was the same for both infected and noninfected lizards (very low in reptiles), but was significantly reduced in active animals. Short bursts of activity (sprint running) were not affected by infection, but stamina running was reduced in infected lizards. Testis size of infected males was reduced as was fat stored by both males and females and the clutch size of females infected with the parasite. Size of eggs, hatching success, and apparent health of offspring were not altered for infected females. Growth rate was not reduced by infection. Mortality of laboratory-maintained lizards was increased in malarious animals. Studies on the effect of parasites on reptile hosts are very few. These results show a blood parasite plays an important role in the physiological ecology and reproduction of the western fence lizard.

2182. Schall, Jos. J., and M. D. Dearing. 1987. **Malarial parasitism and male competition for mates in the western fence lizard, *Sceloporus occidentalis*.** Oecologia 73:389-392.
Abstract: The effect of malarial parasitism on the ability of male western fence lizards, *Sceloporus occidentalis*, to compete for access to females was assessed experimentally. Pairs of male lizards, one infected with the malarial parasite, *Plasmodium mexicanum*, and the other not infected, were matched by size and color and placed in large seminatural outdoor enclosures along with a female fence lizard. Infected males displayed to females and other males less often than did noninfected male lizards. Noninfected lizards were dominant in social interactions more often than malarious animals, based on duration and intensity of agonistic encounters toward the other male, and time spent with the female. Thus, malarial infection hinders the ability of the male fence lizard to compete for mates.


Rebecca Eisen

Western fence lizard blood cells infected with the malarial parasite *Plasmodium mexicanum*

2183. Schall, Jos. J., and Gail A. Sarni. 1987. **Malarial parasitism and the behavior of the lizard, *Sceloporus occidentalis*.** Copeia 1987(1):84-93.
Abstract: The behavioral time budget of the western fence lizard, *Sceloporus occidentalis*, was recorded in northern California, where fence lizards are frequently infected by the malarial parasite, *Plasmodium mexicanum*. Because malarial infection results in pathologies that could affect the host's behavior in nature, time budgets of malarious and noninfected animals were compared. Malarious and noninfected lizards utilized the microhabitat in similar ways, except that infected animals perched more often in the shade. Fully 94% of the time lizards were observed they spent perched, unmoving, and apparently visually scanning the local area. Although behavior patterns differed seasonally and between sexes and age classes, they were very similar in infected and noninfected lizards. Noninfected adult males, though, spent more time engaged in social behaviors than did malarious males. Social interactions appear strenuous, occasionally lasting several minutes. Such social activities by the lizard may depend on rapid oxygen consumption that is disrupted by *Plasmodium* infection. Number of burst runs and length of runs were similar for both infected and noninfected animals; most lasted less than 1 second, and the longest covered 6 m. In laboratory experiments, recovery from burst runs was rapid (less than 1 min/sec of running), probably negating any ecological consequences of an effect of the parasite on rate of metabolic recovery by infected lizards. The behavior of malarious lizards, compared to noninfected animals, can be explained by the effects of *Plasmodium* infection on the host's energy metabolism, as measured in the laboratory. These results demonstrate that estimating the virulence of parasitic infection requires both laboratory studies and observation on the host in a natural setting.

2184. Schall, Jos. J. 1989. **The sex ratio of *Plasmodium* gametocytes.** Parasitol. 98:343-350.
Abstract: Sex ratio theory usually predicts an equilibrium sex ratio and equal proportions of males and females in a population, including

the progenitors of the reproductive cells of protozoans. This proposal was tested with 3 species of malarial parasites of lizards, *Plasmodium mexicanum* of the western fence lizard, and *P. agamae* and *P. giganteum* of the African rainbow lizard, using single samples from naturally infected lizards, repeated samples from free-ranging lizards (*P. mexicanum* only) and repeated samples from laboratory maintained animals. Macrogametocytes were usually more abundant than microgametocytes, and were slightly larger, revealing a typically greater investment of resources by the progenitors of female reproductive cells. However, the proportion of microgametocytes varied among the 3 species and among infections within each species of *Plasmodium*. The sex ratio of gametocytes often remained constant within infections followed over time even if the absolute number of gametocytes was changing. However, the equilibrium sex ratio of gametocytes varied among those infections that had an unchanging microgametocyte proportion. Thus, although an equilibrium sex ratio apparently occurs for most infections, there appears to be no characteristic proportion of microgametocytes for any of the species. Potential explanations for this conflict with theory are presented.

2185. Schall, Jos. J. 1990. **The ecology of lizard malaria.** Parasitol. Today 6(8):264-269.
Abstract: The lizard malarias are a taxonomically and ecologically diverse group of parasites that offer excellent models for research on the ecology of malaria in free-ranging non-human vertebrate hosts. Studies over the past decade show that plasmodia of lizards can play an important role in the ecology and behavior of their hosts. The behavior of malarial infections in lizards also reveals unsuspected variation in the life history of *Plasmodium*. This article reviews malarial parasites that infect lizards world-wide, with examples from studies done at Hopland. Topics covered include the diversity of lizard malarias, course of infection and gametocyte sex ratio, interspecific relationships between *Plasmodium* species, effects of malaria on lizard hosts, and parasite-mediated competition among host species.

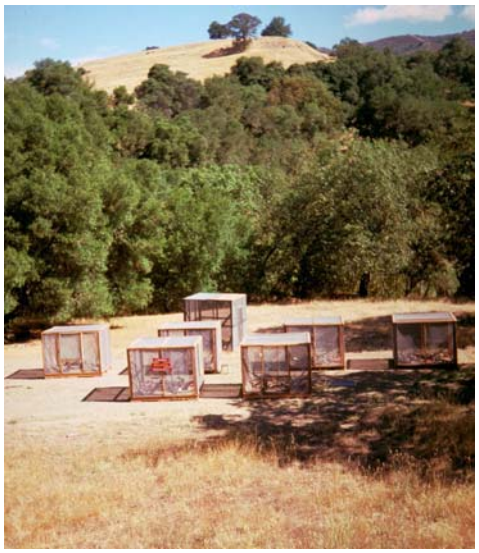
2186. Schall, Jos. J. 1990. **Virulence of lizard malaria: the evolutionary ecology of an ancient parasite-host association.** Parasitol. 100:S35-S52.
Abstract: The negative consequences of parasitic infection (virulence) were examined for 2 lizard malaria parasite-host associations: *Plasmodium agamae* and *P. giganteum*, parasites of the rainbow lizard, *Agama agama*, in Sierra Leone, West Africa; and *P. mexicanum* in the western fence lizard, *Sceloporus occidentalis*, in northern California. These malaria species vary greatly in their reproductive characteristics: *P. agamae* produced only 8 merozoites per schizont, *P. giganteum* yields over 100, and *P. mexicanum* an intermediate number. All 3 parasites appear to have had an ancient association with their host. In fence lizards, infection with malaria is associated with increased numbers of immature erythrocytes, decreased hemoglobin levels, decreased maximum oxygen consumption, and decreased running stamina. Not affected were numbers of erythrocytes, resting metabolism rate, and sprint running speed which is supported by anaerobic means in lizards. Infected male fence lizards had smaller testes, stored less fat in preparation for winter dormancy, were more often socially submissive and, unexpectedly, were more extravagantly colored on the ventral surface (a sexually dimorphic trait) than non-infected males. Females also stored less fat and produced smaller clutches of eggs, and directly observed reduction in fitness. Infected fence lizards do not develop behavioral fevers. *P. mexicanum* appears to have broad thermal buffering abilities and thermal tolerance; the parasite's population growth was unaffected by experimental alterations in the lizard's body temperature. The data are less complete for *A. agama*, but infected lizards suffer similar hematological and physiological effects. Infected animals may be socially submissive because they appear to gather less insect prey, possibly a result of being forced into inferior territories. Infection does not reduce clutch size in rainbow lizards, but may lengthen the time between clutches. These results are compared with predictions emerging from several models of evolution of parasitic virulence. The lack of behavioral fevers in fence lizards may represent a physiological constraint by the lizards in evolving a thermal tolerance large enough to allow elimination of the parasite via fever. Such constraints may be important in determining the outcome of parasite-host coevolution. Some theory predicts low virulence in old parasite-host systems and higher virulence in parasites with greater reproductive output. However, in conflict with this argument, all 3 malarial species exhibited similar high costs to their hosts.

2187. Schall, Jos. J., and Philip R. Houle. 1992. **Malarial parasitism and home range and social status of male western fence lizards, *Sceloporus occidentalis*.** J. Herpetology 26(1):74-76.
Abstract: Male fence lizards were captured at 3 sites, a blood smear made to later determine infection status with malaria, marked with a unique number painted on the back, and then released. These animals were observed over a 50-day period to determine home range size, activity level, and social status. Home range size and minimum number of days the lizards remained at a site were the same for infected and noninfected males. However, noninfected lizards were active more often and were far more likely to be dominant in social situations. These results confirm previous experimental results showing malarial infection reduces the social status of males and their access to females.

2188. Schall, Jos. J., and Azra B. Marghoob. 1995. **Prevalence of a malarial parasite over time and space: *Plasmodium mexicanum* in its vertebrate host, the western fence lizard *Sceloporus occidentalis*.** J. Anim. Ecol. 64:177-185.
Abstract: We studied patterns of abundance of the malarial parasite *Plasmodium mexicanum* in its vertebrate host, the western fence lizard *Sceloporus occidentalis*, over a 13-year period at 51 study sites in northern California. Abundance of the vectors, sandflies in the genus *Lutzomyia*, was also studied among sites during a single warm season, and among nights at one site during 2 seasons. The parasite differed in prevalence (percent of lizards infected) in males and females; males were more often infected. Prevalence increased with body size (= older lizards were more often infected). Malaria prevalence varied among sites: 0-50% of lizards were infected. Topography explains part of this variation because malaria was rare or absent at >500 m elevation. However, sites at lower elevations, even when within short distances of one another, varied in malaria prevalence. Abundance of vectors was not related to prevalence of malaria at a site; sandflies were found at some sites where malaria was rare or absent, including those at high elevations. Wind speed, relative humidity, and sky brightness did not affect numbers of sandflies active, but vectors were active only when air temperature was >16°C. Parasite prevalence varied among years. Environmental conditions (temperature, rainfall and plant biomass produced at the study region) were not correlated with parasite prevalence. The changes in prevalence over time resembled a cycle of long duration (10 years). Classical models developed for study of malaria in humans suggest explanations for variations in prevalence of *P. mexicanum* among sites, and a more recent theory suggests an explanation for the possible long-duration cycle observed in this study.

2189. Schall, Jos. J. 1996. **Malarial parasites of lizards: diversity and ecology.** Advances in Parasitol. 37:255-333.
Abstract: Parasitism was generally ignored by the majority of ecologists, evolutionary biologists, and behaviorists until recently. In the past 10 years, a renaissance of interest in parasites has dominated evolutionary ecology. If ecologists have long ignored parasites as

subjects of study, then parasitologists are guilty of neglecting malaria in lizards as a productive system for general studies of parasite biology. The great diversity of known species of *Plasmodium* infecting lizards, their wide distribution, their ecologically important variation in reproductive traits, and the ease with which lizards can be collected, housed, and observed all argue for the usefulness of lizard malaria for future studies in parasite ecology and evolution. Malaria plays a major role in every aspect of the lizard host that has been examined. This chapter summarizes the diversity and distribution of malarial parasites of lizards. Descriptions of the main study site at Hopland, CA utilized by the author and his students, as well as of additional study sites in Sierra Leone, west Africa and the Caribbean, are given. The chapter reviews prevalence of malarial infections, course of infection, the sex ratio of gametocytes, interaction between malarial species, vector biology, and factors affecting virulence in the vertebrate host.



Robert J. Keiffer

Lizard cages for Joe Schall's lizard malaria studies, headquarters area, October 1997

2190. Schall, Jos. J. 2000. **Transmission success of the malaria parasite *Plasmodium mexicanum* into its vector: role of gametocyte density and sex ratio.** Parasitol. 121:575-580.
Abstract: The life cycle of malaria parasites (*Plasmodium* spp.) depends on transmission of the parasite from the vertebrate host to its insect vector when the vector takes a blood meal. This transmission success is highly variable and may depend on the parasite gametocyte density in the blood and the sex ratio of those gametocytes. *P. mexicanum*, a parasite of lizards in northern California, uses the sandfly *Lutzomyia vexator* as its vector. In experimental transmissions using naturally infected lizards as donors of blood, transmission success (measured as percent of vectors infected and number of parasite oocysts on the insect's midgut) was positively related to gametocyte density, although gametocyte density above 20/1000 erythrocytes did not improve transmission. Sex ratio (proportion of microgametocytes in the infection) was positively correlated with gametocyte density. Transmission success improved with higher proportion of microgametocytes for 2 of 3 months of the experiments, but this was a result only of higher gametocyte densities. These results agree with most previously published results on gametocyte density and the few papers published on sex ratio, but present an interesting challenge to sex ratio theory and the theory of parasite virulence.

2191. Schall, Jos. J., Holly R. Prendeville, and Kathryn A. Hanley. 2000. **Prevalence of the tick, *Ixodes pacificus*, on western fence lizards, *Sceloporus occidentalis*: trends by gender, size, season, and mite infestation.** J. Herpetology 34(1):160-163.
Abstract: In northern California the western fence lizard, *Sceloporus occidentalis*, is often infested with larvae and nymphs of the black-legged tick, *Ixodes pacificus*. Lizards were monitored for ticks and mite ectoparasites at one site in northern California (Hopland) and two sites in southern California (Rancho Santa Ana Botanic Garden, and Evey Canyon). At Hopland, at first capture 130 lizards were infested with 0-78 ticks; only 9% lacked any ticks. Males hosted more ticks than females, and larger males carried more ticks. It was shown that the larger number of ticks infesting males was not a result of differing body size by gender. Most ticks were attached in the nuchal pockets. For all sites, mites (primarily *Geckobiella* spp., the mechanical vector of *Schellackia occidentalis*, a common protozoan parasite of the lizards' intestine and blood) were also common on the lizards at first capture (0-64), but mites were not congregated in the nuchal pockets. Only 12% of lizards were free of mites, while 75% lizards carried 1-20 mites. Both mites and ticks were extremely common at Hopland, where almost all of the lizards carried both kinds of ectoparasite. No relationship was observed for body condition vs. number of ticks at first capture. Observations suggest the two kinds of ectoparasites have different ecologies, but there may be some ecological interaction between ticks and mites. There is a negative relationship between the number of ticks and mites on individual lizards. There appears to be a seasonal shift, with ticks exploiting lizards more in early summer and mites more later in the season. Seasonal and geographical variation in attachment by *I. pacificus* on fence lizards is of interest because of the potential role of the lizards in limiting the prevalence of Lyme disease.

2192. Schoeler, George B., and Robert S. Lane. 1993. **Efficiency of transovarial transmission of the Lyme disease spirochete, *Borrelia burgdorferi*, in the western blacklegged tick, *Ixodes pacificus* (Acari: Ixodidae).** J. Med. Entomol. 30(1):80-86.
Abstract: The efficiency of transovarial transmission of *Borrelia burgdorferi* was evaluated in *Ixodes pacificus* collected from 2 areas of Northern California where Lyme disease is endemic. In total, 132 (8.8%) of 1,499 replete females examined by direct immunofluorescence were demonstrated to be infected with *B. burgdorferi*. Larvae or eggs from 119 of these females were examined for the presence of spirochetes by direct immunofluorescence, placing them in culture, or both; none was found to contain *B. burgdorferi*. The fecundity of 20 midgut-infected and 20 uninfected *I. pacificus* females did not differ statistically. Likewise, the fertility of infected and uninfected females and the mean engorged weights of both groups were comparable. The fecundity, fertility, and mean weights of 6 replete females having ovarian infections, 6 females having midgut-restricted infections, and 6 uninfected females were also similar. We conclude that transovarial transmission is not efficient for maintaining *B. burgdorferi* in populations of *I. pacificus*, a known vector of that pathogen. Infection with the spirochete does not appear to affect either feeding or reproductive success adversely in females of this tick.

2193. Slowik, Ted J., and Robert S. Lane. 2001. **Nymphs of the western black-legged tick (*Ixodes pacificus*) collected from tree trunks in woodland-grass habitat.** J. Vector Ecol. 26(2):165-171.
Abstract: Nymphs of the western black-legged tick, *Ixodes pacificus*, were found on the trunks of trees during spring and summer in northwestern California. In a woodland-grass habitat, large- and medium-sized (>130 cm and 80 - 130 cm in circumference, respectively), moss-covered oak (*Quercus* spp.) trees supported ticks significantly more often than trees without these characteristics. Additionally, trees with basal leaf-litter and lacking shade (at time of sampling) were significantly associated with the presence of ticks. Mean tick-burdens were >1 for all oaks (1.06), all trees with basal

leaf-litter (1.05), and all trees of large-circumference (1.19); 0.79 ticks per tree were collected over the entire study. Moss reduced the surface temperature of trees by a mean of 1.9°C (range of 1.6 - 5.0°C) and increased relative humidity by up to 2.5% from the ambient. These microclimate changes, along with the presence of refugia in bark and western fence lizard (*Sceloporus occidentalis*) hosts on the lower-most surface of trees, likely accounted for ticks questing on the trunks. Although of undetermined epidemiological significance, the presence of host-seeking *I. pacificus* nymphs on tree trunks may shed light on the relation of abiotic and biotic factors to the life history of this important vector of disease.

2194. Slowik, Ted J., and Robert S. Lane. 2001. **Birds and their ticks in northwestern California: minimal contribution to *Borrelia burgdorferi* enzootiology.** J. Parasitol. 87(4):755-761.
Abstract: Birds and their attendant ticks were surveyed for infection with the Lyme disease spirochete, *Borrelia burgdorferi*, in chaparral and woodland-grass habitats in northwestern California from March to July, 1998 to 1999. In total, 234 birds were captured and recaptured (15%); nearly 2.5 times more birds were captured in chaparral than in woodland-grass. Overall, 34 species representing 15 families were collected during this study; of these, 24 species were caught in chaparral, 19 in woodland-grass, and 9 in both vegetational types. The most frequently captured birds were sage sparrows (*Amphispiza belli*) in chaparral, and American robins (*Turdus migratorius*) and oak titmice (*Baelophus inornatus*) in woodland-grass. Birds hosted 35 *Ixodes pacificus* (15 larvae, 20 nymphs) and 9 *Haemaphysalis leporispalustris* (3 larvae, 5 nymphs, 1 adult) ticks, of which 32 were removed from chaparral birds and 12 from woodland birds. The prevalence of tick infestation was 13% (21/167) in chaparral and 5% (3/67) in woodland-grass, but the relative and mean tick intensities of 0.19 and 1.5 for chaparral birds, and 0.18 and 4.0 for woodland birds, respectively, did not differ significantly by habitat. Spirochetes were not detected in either bird-blood or tick-tissue samples when tested by culture, immunofluorescence, or Giemsa-staining. In contrast, over 90% (86/94) of western fence lizards (*Sceloporus occidentalis*) collected in June or July were infested with an average of 6.9 and 8.9 immature *I. pacificus* in chaparral and woodland-grass, respectively. We conclude that birds contribute little to the enzootiology of *B. burgdorferi* in chaparral and woodland-grass habitats in northwestern California because of their limited parasitism by tick vectors and lack of detectable spirochetemias.

2195. Slowik, Ted J., Robert S. Lane, and Richard M. Davis. 2001. **Field trial of systemically delivered arthropod development-inhibitor (fluazuron) used to control woodrat fleas (Siphonaptera: Ceratophyllidae) and ticks (Acari: Ixodidae).** J. Med. Entomol. 38(1):75-84.
Abstract: An orally delivered arthropod development-inhibitor (fluazuron) was evaluated for its potential to reduce the number of flea and tick vectors found on the dusky-footed woodrat *Neotoma fuscipes*, a reservoir host important in disease enzootiology in northern California. Pigmented bait cubes containing fluazuron were distributed monthly to woodrat nests in a chaparral habitat for 1 year. When compared with control woodrats, the numbers of fleas (primarily *Orchopeas sexdentatus*) on treated woodrats were significantly reduced 3-4 months after initial application, and remained so for the duration of the application period. By contrast, tick numbers were not significantly reduced on treated woodrats. After the cessation of treatments, flea indices remained lower on treated animals for up to 2 months after application. Approximately 93% of distributed bait cubes were removed by woodrats, which indicates that the bait cube formulation and delivery system were highly effective. Bait cubes also were attractive to small rodents and ground-frequenting birds. The results of this study suggest that a monthly application program of fluazuron delivered by bait cube is effective in reducing woodrat flea-burdens, but is not effective, at least in the short-term, in controlling ticks.

2196. Tälleklint-Eisen, Lars, and Rebecca J. Eisen. 1999. **Abundance of ticks (Acari: Ixodidae) infesting the western fence lizard, *Sceloporus occidentalis*, in relation to environmental factors.** Experimental and Applied Acarology 23:731-740.
Abstract: We examined the impact of environmental characteristics, such as habitat type, topographic exposure, and presence of leaf litter, on the abundance of *Ixodes pacificus* ticks infesting the western fence lizard (*Sceloporus occidentalis*) at the UC Hopland Research and Extension Center (HREC). A total of 383 adult lizards were slip-noosed and examined for tick infestation in April and May 1998. At least 94% of the lizards infested by ticks and at least 20% of the females and 33% of the males carried >15 ticks. This intensive utilization of western fence lizards (which do not serve as natural reservoirs for Lyme disease spirochetes) by subadult ticks, is probably the primary reason for the low prevalence of infection with *Borrelia burgdorferi* in *I. pacificus* nymphs and adults previously recorded at the HREC. Tick loads were higher on male than female lizards. Also, male lizards were generally more heavily infested in late April than in late May. The prevalence of tick infestation exceeded 88% in all habitat types but males collected in woodland and grass/woodland edges had higher tick loads than those collected in open grassland. Male lizards captured in open, exposed grassland tended to carry heavier tick loads in northern/eastern, as compared to southern/western, exposures, and when leaf litter was present.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UC Berkeley graduate student Kerry Padgett removes ticks from fence lizard, April 1996

2197. Tälleklint-Eisen, Lars, and Robert S. Lane. 1999. **Variation in the density of questing *Ixodes pacificus* (Acari: Ixodidae) nymphs infected with *Borrelia burgdorferi* at different spatial scales in California.** J. Parasitol. 85(5):824-831.
Abstract: The density of, and prevalence of infection with *Borrelia burgdorferi* in, *Ixodes pacificus* nymphs as well as the density of infected nymphs were compared at 12 properties at a small rural community at high risk for Lyme disease (CHR) and at 12 areas at the University of California Hopland Research and Extension Center (HREC). The mean infection prevalence and density of infected nymphs were 1.7% (range 0 - 4.2%) and 0.10 infected nymphs per 100 m^2 (range 0 - 0.23 per 100 m^2) at the HREC, and 12.4% (range 3.9 - 41.3%) and 1.83 infected nymphs per 100 m^2 (range 0.29 - 22.17 per 100 m^2) at the CHR. Thus, the mean density of infected nymphs differed 18-fold between CHR and HREC and 76-fold between properties at the CHR. Also, there was up to 10-fold variation in infection prevalence and 16-fold variation in density of

infected nymphs between discreet areas within properties at the CHR. The high densities of infected nymphs recorded at the CHR suggest that, despite the low statewide incidence of Lyme disease, the medical community should be alerted that Lyme disease can be highly endemic in rural areas of northwestern California. The prevalence of spirochetal infection was higher for nymphs collected in southern/western, as compared to northern/eastern, exposures at both HREC and CHR. Infection prevalence and nymphal density were negatively associated at the HREC, whereas they tended to be associated positively at the CHR. A positive association was observed between nymphal density and density of infected nymphs when data from CHR and HREC were combined, and when data from the CHR were considered alone, but not for data from the HREC alone.

2198. Tälleklint-Eisen, Lars, and Robert S. Lane. 2000. **Efficiency of drag sampling for estimating population sizes of *Ixodes pacificus* (Acari: Ixodidae) nymphs in leaf litter.** J. Med. Entomol. 37(3):484-487.
Abstract: Drag sampling is a commonly used method to obtain relative estimates of the density of questing nymphal *Ixodes scapularis* and *I. pacificus* ticks, which are primary vectors of Lyme disease spirochetes to humans in North America. However, the efficiency of drag sampling in determining absolute population densities of questing nymphs has not been evaluated previously. Therefore, we assessed the efficiency of a single drag-sampling occasion to estimate the total population size of questing *I. pacificus* nymphs in leaf-litter habitat in California. Repeated daily removal sampling was carried out in 4 areas, each covering 300 m^2, on 17 occasions over a 23-day period in the spring of 1999. In total, 573 *I. pacificus* nymphs were collected, of which 55 (9.6%) were collected on the initial sampling occasion and 20 (3.5%) on the last occasion. The total population size of questing nymphs, i.e., the intersection with the horizontal axis of a linear regression of daily nymphal catch rates on the number of nymphs caught previously, was estimated to be 936. Thus, the efficiency of the initial sampling occasion to estimate the total population size was 5.9% (4.8, 5.0, 5.8, and 9.1%, respectively, for the 4 individual sampling areas). Further, the overall mean efficiencies of the 2, 5, and 10 first removal sampling occasions to estimate the absolute nymphal density was 5.3, 4.7, and 4.3%, respectively, and 13 sampling occasions were required to collect 50% of the estimated total nymphal population.

2199. Tälleklint-Eisen, Lars, and Robert S. Lane. 2000. **Spatial and temporal variation in the density of *Ixodes pacificus* (Acari: Ixodidae) nymphs.** Environ. Entomol. 29(2):272-280.
Abstract: The nymphal and adult life stages of the western black-legged tick, *Ixodes pacificus*, are the primary vectors of the causative agent(s) of Lyme disease in the far-western United States. In contract to *I. pacificus* adults, data on the extent of spatial and temporal variation in the density of the nymphal stage have been scarce. Therefore, we compared the density of *I. pacificus* nymphs from 1997 to 1999 at a small rural community at high risk for Lyme disease (CHR) and the UC Hopland Res. & Ext. Center (HREC), Mendocino Co., California. *I. pacificus* nymphs were collected readily by drag sampling in leaf litter but not from low vegetation. The mean number of questing nymphs per 100m^2 in leaf/fir-needle litter areas from late April to early June differed significantly among years both at the CHR and the HREC. Climatic data from the HREC suggested that yearly nymphal densities in this area may be positively correlated with the amount of rainfall and negatively correlated with maximum temperatures from March to May. Further, nymphal density was 2 to 4 times higher at the CHR than the HREC in all 3 years. Yearly means nymphal density generally differed 2- to 4-fold (HREC) and 10- to 20-fold (CHR) among individual sampling area. Also, 2- to 3-fold differences in mean nymphal density were frequently observed between continuous litter and litter edges bordering on other habitats within sampling areas at the HREC, and between sampling areas <100m apart at the CHR. The distributions of nymphs within individual areas were generally aggregated at both the HREC and the CHR at the 15-m sampling transect scale we used. Environmental factors with some potential to predict the density of *I. pacificus* nymphs at different spatial scales included climatic conditions, topographic exposure, and presence of habitat edges or logs. However, stepwise multiple regression analysis revealed that only 6.2 - 18.0% (HREC) or 14.9 - 27.9% (CHR) of the yearly variation in nymphal densities was explained by the abiotic or biotic traits measured in this study, at the 15-m transect scale. Thus, other abiotic or biotic traits that we did not examine (e.g., local densities of tick hosts) must account for most of the spatial variation in nymphal density.

2200. Timm, Robert M., and Robert S. Lane. 1993. **Lyme disease: incidence and prevention, with emphasis on wildlife biologists (Abstract).** P. 217 *in:* Proc. 11th Gt. Plains Wildl. Damage Control Wkshp., Kansas City, MO, Apr. 26-29.
Abstract: Lyme disease, a potentially debilitating illness in humans if untreated, is caused by the spirochete *Borrelia burgdorferi*. First recognized in the mid-1970s in Lyme, Connecticut, the disease has been reported in at least 46 states of the United States and in Canada, Australia, Asia, and Europe. This disease is primarily transmitted to humans by tick bite. In California, the tick believed primarily responsible is the western black-legged tick, *Ixodes pacificus*. In the upper midwestern and northeastern states, the usual vector is *Ixodes scapularis* (formerly *I. dammini* in part). Other potential modes of transmission to humans include horseflies, deerflies, and mosquitoes, which have been implicated as potential secondary vectors of *B. burgdorferi* in Europe and the northeastern United States. Of greater concern to wildlife biologists is the potential for direct contact transmission, which may occur through unbroken skin when humans are exposed to the tissues or bodily fluids of infected animals. In northern California, spirochetes tentatively identified as *B. burgdorferi* have been detected in blood of native Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in the late fall and winter, as well as in introduced axis and fallow deer. In the northeastern United States, direct contact transmission has been reported from infected to uninfected white-footed mice (*Peromyscus leucopus*), and spirochetes have been detected in the urine of naturally infected *P. leucopus*. People appear to be at risk in spring and summer, when nymphal ticks are most abundant. Wildlife biologists who spend significant time out-of-doors are at higher risk than most other segments of the population. The best means of preventing the disease is to avoid tick bites. Common precautions include wearing appropriate dress when out-of-doors, avoiding vegetation and leaf litter where ticks may be seeking hosts, using registered tick repellents, and checking yourself for ticks frequently and thoroughly following field work. Common antibiotics will usually cure Lyme disease if given within the first few weeks of infection. If treatment is delayed, however, the disease can lead to arthritic, cardiac, or neurological problems weeks or months later, and may become much more difficult to cure.

2201. Turner, William J. 1971. **Biosystematics of the California species of the genus *Symphoromyia* (Diptera: Rhagionidae).** Ph.D. Dissertation, Univ. Calif. Berkeley. 412 pp.
Abstract: The intent of this thesis is to present a systematic review of *Symphoromyia* species occurring in California. Eleven previously named species are treated in addition to twenty-three which are described as new. Species are characterized primarily on the basis of external adult morphology but observational data taken from male swarms has been considered as well. Most species of *Symphoromyia* are restricted to western North America. Seventy percent of the western species occur in California and three-quarters of these appear to be endemic to the state. Several species are essentially montane in

distribution and associated with cool- and temperate-adapted coniferous elements. Others appear to be restricted to more xeric foothill and oak-woodland areas. All living Nearctic species can be conveniently and naturally grouped into nine distinct species groups which probably represent five or six basic stocks of phyletic lines. Nine species groups are recognized and keys are provided for their separation. A paleohistory of the species in California is proposed based on present distribution patterns, paleobotanical and paleoclimatic evidence. Speciation appears to be relatively recent judging from the high degree of morphological similarity between closely related species. Present montane species were probably formed after fragmentation by Pleistocene glaciation while lowland populations were isolated by changing climatic conditions, diverse topography or possibly be shifts in female host ranges. Adequate larval habitats may also have been a factor in determining present distributions. It is suggested that female haematophagous behavior probably had little influence on their evolution. Previous reports of *Symphoromyia* swarming are limited to several brief accounts. In this study field observations revealed that twenty-one species form species-specific aggregations which are organized to specific swarm markers and occur in different portions of the habitat. Criteria for swarming were established to be: 1) sustained serial assembly of two or more flies; 2) orientation to a marker or particular area; 3) rhythmic hovering or dance movements or coursing about in a confined air space; 4) restriction primarily to males. Two basic types of *Symphoromyia* swarms are recognized: 1) marker swarms (i.e., spherical or vertically orientated, columnar aggregations, formed at various heights but usually associated with vegetation and shade; individual station holding within the swarm and dancing characteristic; swarm marker usually apparent) and 2) free swarms (i.e., horizontal, flat swarms comprised of coursing individuals, occurring at various heights over bare ground or vegetation, and formed in open areas in full sunlight, rarely in shade; swarm markers less obvious). Further breakdown of these basic swarm types permitted association of species on the basis of similarities in physical appearance of the aggregation, location of the swarm, type of marker, and time of swarming. It was concluded that types of swarms and their subdivisions do not usually follow taxonomic lines. Rather several common features of a single swarm type may be observed in species of different phyletic stocks. For this reason it is believed that types of *Symphoromyia* swarms are polyphyletic and convergently evolved as isolating mechanisms by groups of sympatric species which were derived from different phyletic lines.

2202. Turner, William J., and J. G. Chillcott. 1973. **Four new species of the *Symphoromyia pachyceras* complex from California.** Pan-Pac. Entomol. 49(1):5-20.
Abstract: The Nearctic species of biting snipe flies of the genus *Symphoromyia*, last revised in 1915, remain poorly known. On morphological bases, including the structure of the male genitalia, the species can be divided into several distinct groups or complexes. One group, the *pachyceras* complex, was found to contain several new entities. Four species, all from northern California and closely related to *S. pachyceras* are described: *S. cervivora*, *S. inconspicua*, *S. nana*, and *S. truncata*. The holotype males are all collected from the Hopland Field Station.

2203. Turner, William J. 1976. ***Fannia thelazine*, a new species of eye-frequenting fly of the *benjamini* group from California and description of *F. conspicua* female (Diptera: Muscidae).** Pan-Pac. Entomol. 52(3):234-241.
Abstract: A taxonomic description is given of a new species of fly, *Fannia thelaziae.* This fly is common to dry chaparral and oak woodland areas throughout California. It is shown to serve as the intermediate host of the mammalian eyeworm, *Thelazia californiensis*, which infests a variety of mammal hosts including deer, rabbits, dogs, and humans. The author provides descriptions, illustrations, and a key to species of the *benjamini* subgroup within the genus *Fannia.* Included is a taxonomic description of a female *F. conspicua*.

2204. Walker, David H., Alan G. Barbour, James H. Oliver, Robert S. Lane, J. Stephen Dumler, David T. Dennis, David H. Persing, Abdu F. Azad, and Edward McSweegan. 1996. **Emerging bacterial zoonotic and vector-borne diseases: ecological and epidemiological factors.** J. Am. Med. Assoc. 275(6):463-469.
Abstract: Among the etiologic agents of emerging infectious diseases are several bacterial organisms that naturally reside in animal and arthropod hosts. The most compelling emerging bacterial zoonotic and vector-borne diseases in the United States are Lyme disease; a Southern erythema migrans-like illness; human monocytic ehrlichiosis; human granulocytic ehrlichiosis; a novel cat flea-associated typhus group rickettsiosis; bartonelloses of immunocompetent and immunocompromised persons, particularly with AIDS; and sylvatic plague. Some of these antimicrobial-treatable infections are life threatening. During the acute stage of illness when antimicrobial agents are most effective, the flu-like clinical signs and symptoms and available laboratory tests frequently do not point to a particular diagnosis. Epidemiological factors determined by the ecology of the bacteria are often the most useful diagnostic clues. The recognition of these evolving problems emphasizes the need for development of better laboratory diagnostic methods, for surveillance for tracking of disease, and for continued research into factors contributing to transmission of the organisms. The continual appearance of previously unidentified bacterial infections requires prospective national strategies for timely recognition of the syndrome, identification of the agent, establishment of criteria and methods for diagnosis, optimization of the treatment regimen, and determination of successful approaches to prevention and control.

2205. Washburn, Jan O., and John R. Anderson. 1986. **Distribution of *Lambornella clarki* (Ciliophora: Tetrahymenidae) and other mosquito parasites in California treeholes.** J. Invert. Pathol. 48:296-309.
Abstract: *Lambornella clarki* was one of 3 common parasites infecting larvae of *Aedes sierrensis* from California treeholes sampled between 1983 and 1985. *Lambornella* occurred in 37 of 142 treeholes and was absent from holes with extremes of pH and high electrical conductivity. Ciliates were more common in treeholes in northern California, and *L. clarki* from all holes was pathogenic to *A. sierrensis.* Natural infection rates averaged 16.1% but reached 100% in some holes suggesting that epizootics may occur in natural host populations. Free-swimming trophozoites appeared shortly after treeholes flooded, but their numbers declined in subsequent samples. Predation by *A. sierrensis* larvae and successful attack and entry of hosts probably accounted for this decline. Trophozoites were common in treehole water late in the season as adult mosquitoes were emerging, and these were probably released from moribund and dead infected hosts. The parasite persisted in dry treeholes between wet seasons in 90% of the cases indicating a highly efficient desiccation-resistant cyst. *Octomyomermis troglodytis* (Nematoda: Mermithidae) and *Ascogregarina clarki* (Sporozoa: Eugregarinida) were found in 17 and 46 treeholes, respectively. The co-occurrence of the parasites and *L. clarki* within treeholes did not deviate from random, indicating that parasites are not segregated among larval habitats. All combinations of parasites were found within individual hosts suggesting that competitive forces in this parasite guild are probably weak.

2206. Washburn, Jan O., John R. Anderson, and David E. Egerter. 1986. **Distribution and prevalence of *Octomyomermis troglodytis* (Nematoda: Mermithidae), a parasite of the western treehole mosquito, *Aedes sierrensis*.** J. Am. Mosq. Control Assoc. 2(3):341-346.

Abstract: *Octomyomermis troglodytis* was found infecting western treehole mosquito, *Aedes sierrensis,* larvae in 14.5% of 165 treeholes sampled between 1982 and 1986. Mermithid infections were detected in treehole waters that ranged in pH from 6.5 to 9.3 and electrical conductivities between 0.10 and 5.11 mmhos/cm. Third and fourth instar larvae were most frequently infected, and most immatures that succumbed to infections died while in the fourth instar. Most hosts contained only one nematode. Infected adults were obtained from emergence traps over treeholes, from field-collected immatures reared in the laboratory, and from mosquito collections from sentinel humans. *Octomyomermis troglodytis* escaped from adults into water vials in the laboratory, suggesting that infected adult mosquitoes serve as dispersal agents for this parasite.

Jan Washburn

Adult female western treehole mosquito obtains a blood meal from UC Berkeley researcher Jan Washburn's arm

2207. Washburn, Jan O., John R. Anderson, and David E. Egerter. 1986. **Parasitism of *Aedes sierrensis* by *Octomyomermis troglodytis* (Nematoda: Mermithidae) in California treeholes (Abstract).** P. 147 *in:* Proc. Ann. Conf. Calif. Mosq. Vector Control Assoc., Vol. 54, Redding, CA, Mar. 16-19.
Abstract: The nematode *Octomyomermis troglodytis* is a recently-described natural enemy of the western treehole mosquito, *Aedes sierrensis.* Previously, this parasite was known only from a single treehole in Marin County, California; from field investigations of natural enemies affecting mosquito populations, we have 384 records of mermithid-infected mosquitoes from 24 treeholes. This paper presents new findings on the distribution, biology, dispersal, and habits of this little-known mermithid.

2208. Washburn, Jan O., and John R. Anderson. 1988. **The importance of interactions between the parasitic ciliate, *Lambornella clarki* and the mosquito, *Aedes sierrensis*, on the community structure of California treeholes (Abstract).** P. 171 *in:* Proc. XVIII Int. Congress of Entomology, Vol. VS8, Vancouver, B.C., Canada.
Abstract: *Aedes sierrensis* and *Lambornella clarki* are widespread inhabitants of treeholes on the west coast of North America. Most treeholes support dense larval populations that are subject to food limitation and intense intraspecific competition. In nature, larval feeding can eliminate populations of microbial prey from treehole water. *Lambornella* escapes predation by parasitizing their would-be predator. Larvae release a waterborne factor that induces morpho-genesis of free-living *L. clarki*; induced ciliates transform into parasitic cells that encyst on larval predators. Ciliates penetrate the cuticle and enter the hemocoel where they multiply and ultimately kill their host. In nature, larval populations are reduced or eliminated by multiple parasite cycles which occur over the prolonged period of larval development. In addition to modulating the number of emerging adult mosquitoes, facultative parasitism by *L. clarki* relaxes larval predation pressure allowing for increases in populations of protozoans and other microorganisms.
2209. Washburn, Jan O., David E. Egerter, John R. Anderson, and Gary A. Saunders. 1988. **Density reduction in larval mosquito (Diptera: Culicidae) populations by interactions between a parasitic ciliate (Ciliophora: Tetrahymenidae) and an opportunistic fungal parasite (Oomycetes: Pythiaceae).** J. Med. Entomol. 25(5):307-314.
Abstract: Larvae of the western treehole mosquito, *Aedes sierrensis*, are attacked in nature by the parasitic ciliate *Lambornella clarki*. During their attack, ciliates encyst on the larval cuticle, form a small hole in the integument, and invade the host's hemocoel. Ciliatosis is chronic and fatal; in nature, infected mosquitoes die in approximately 3 weeks. Cuticular penetration provides a portal of entry for invasion by facultatively parasitic fungi and bacteria. These normally saprophytic organisms produce secondary infections that are rapidly fatal to both the host and its primary parasite. In laboratory experiments, cultures of a saprophytic oomycete *Pythium flevoense* produced motile zoospores that encysted and germinated on cuticular cysts of *L. clarki*. If hyphae successfully entered the invasion hole, secondary infections of *P. flevoense* killed most first- and third-instar mosquitoes and their ciliate parasites within 72 hours of ciliate entry into the hemocoel. In mixed populations of *L. clarki*-infected and uninfected larvae, *P. flevoense* selectively invaded *L. clarki*-infected larvae, resulting in reduced mosquito densities. Premature death by secondary infections of larvae infected with ciliates was positively correlated with the density of zoospores in the water.

2210. Washburn, Jan O., Michael E. Gross, David R. Mercer, and John R. Anderson. 1988. **Predator-induced trophic shift of a free-living ciliate: parasitism of mosquito larvae by their prey.** Science 240:1193-1195.
Abstract: Larvae of the treehole mosquito, *Aedes sierrensis*, release a waterborne factor that induces morphogenesis of one of their prey, the tetrahymenid ciliate *Lambornella clarki*. Induced free-living trophonts of *L. clarki* undergo a synchronous response in which cells divide and transform into parasitic cells (theronts) that encyst on larval predators. Parasitic ciliates penetrate the cuticle, enter the hemocoel, and ultimately kill their predator-host. In nature, this trophic shift can lead to predator extinction and dramatic changes in microbial populations. Facultative parasitism by this polymorphic ciliate may have evolved as an antipredator strategy. The experimentally inducible parasitic response of *L. clarki* provides a novel model for studying cellular morphogenesis of ciliated protozoa.

2211. Washburn, Jan O., and John R. Anderson. 1990. **Assessing *Lambornella clarki* as a potential biological control agent for *Aedes albopictus*.** Pp. 133-136 *in:* Proc. Calif. Mosq. Vector Control Assoc., Vol. 57, Los Angeles, CA, Jan. 29 - Feb. 1, 1989.
Abstract: In 1988 we initiated research to evaluate the potential for the Asian tiger mosquito, *Aedes albopictus*, to become established in California. One major objective was to assess the suitability of *Ae. albopictus* as a host for the parasitic ciliate *Lambornella clarki.* The mosquito, first discovered in Texas in 1985, is now present throughout much of the eastern and southern regions of the U.S. Preliminary results demonstrate that larvae of *Ae. albopictus* meet two of the criteria necessary for being a suitable host for *L. clarki.* Specifically, *Ae. albopictus* larvae induce trophont populations at rates that are equivalent to the natural host, and they are recognized as hosts by theronts. While the encystment response of the SF strain of *L. clarki* is strongly biased towards *Ae. sierrensis*, we need to conduct replicated tests with different strains of *L. clarki* to quantify potential differences in host preference. We are currently maintaining 7 strains of *L. clarki* in our laboratory *in vitro*. It may also be possible to employ laboratory selection for developing strains that exhibit an enhanced preference for *Ae. albopictus.* Finally, in addition to these aspects of host suitability, other responses, such as

parasite amplification and dispersal by infected adults, need to be examined before the potential of *L. clarki* as a biological control agent for *Ae. albopictus* can be evaluated.

2212. Washburn, Jan O., and John R. Anderson. 1990. **Epizootics of *Lambornella clarki*: local extinctions of natural treehole populations of *Aedes sierrensis*.** Pp. 137-138 *in:* Proc. Calif. Mosq. Vector Control Assoc., Vol. 57, Los Angeles, CA, Jan. 29 - Feb. 1, 1989.
Abstract: The parasitic ciliate *Lambornella clarki* causes the natural extinction of western treehole mosquito *Aedes sierrensis* populations in certain treeholes. Ciliate epizootics can often be predicted from data on events occurring shortly after treeholes first flood with rainwater, particularly the success of the first wave of theront attack. The intensity and success of the first parasitic cycle which begin with theront encystment on first instar larvae of *Ae. sierrensis* is modulated by a variety of density-dependent and independent factors. For example, both the nutrient availability and water temperature influence the molt schedule of larvae and may calibrate the level of successful ciliate infections in the first cohort of larvae. These and other factors, interacting in complex ways, may set the tempo for subsequent parasite cycles during the prolonged period of larval development by modulating the densities of both host and parasite populations.

2213. Washburn, Jan O., John R. Anderson, and David R. Mercer. 1989. **Emergence characteristics of *Aedes sierrensis* (Diptera: Culicidae) from California treeholes with particular reference to parasite loads.** J. Med. Entomol. 26(3):173-182.
Abstract: Wing lengths, emergence times, and parasite loads were determined for 8,444 newly emerged adult *Aedes sierrensis* collected from 17 treehole emergence traps during a sampling period of 149 days. Peak adult emergence occurred in late spring and early summer, but a small second cohort developed in treeholes retaining water through the dry season. Mosquito production was significantly and positively correlated with the maximum volumes of treeholes. Male and female wing lengths and eclosion times varied significantly among populations from different treeholes; within a population, these variables were highly correlated, suggesting that larvae of both sexes respond similarly to treehole conditions. Egg number (but not longevity) was correlated with adult size for laboratory-maintained females collected from emergence traps. These results suggest variation in the vector potential of adult populations produced from different treeholes. Newly emerged mosquitoes were infected by 5 parasite species that depend on adult hosts for their dispersal. The mermithid nematode *Octomyomermis troglodytis* and the ciliate *Tetrahymena* sp. were very rare in adult populations. Gamontocysts of the ascogregarine *Ascogregarina clarki* infected the Malpighian tubules of adults from 6 treeholes. Ectoparasitic larval water mites (near *Euthyas*) were found on 12% of all adults eclosing from 8 treeholes and selectively parasitized female hosts over males. The ciliate *Lambornella clarki* was the most common parasite; it infected males and females from 7 treeholes in equal proportions. *L. clarki* has a significant negative impact on adult populations in that 13% of all females from *L. clarki*-positive treeholes were infected with ciliates, and infected females are parasitically castrated.

2214. Washburn, Jan O., and John R. Anderson. 1990. **Insect ciliates: potential for container-breeding mosquitoes.** Pp. 507-511 *in:* V Int. Colloquium on Invertebrate Pathology, Adelaide, Australia.
Abstract: About a dozen described species of ciliates are contained in the two closely-related genera, *Tetrahymena* and *Lambornella* (Ciliophora: Tetrahymenidae). Host associations within these genera vary, and species have been categorized as obligatory parasitic, facultatively parasitic, or facultatively free-living; however, host relationships and life cycles of most species are poorly understood, and designations are certain to change. Traditionally, larval populations of container-breeding mosquitoes have been difficult to control because their developmental sites are cryptic and widely dispersed in the environment. Since infected adults mosquitoes serve as dispersal agents of ciliate parasites, it may be feasible to mass produce and release laboratory infected individuals to disseminate the parasite into new habitats. Of the parasitic ciliates, *L. clarki* is the best understood and the most promising for use as a manipulated biological control agent.

UC Berkeley entomologist Jan Washburn uses a portable vacuum to capture treehole mosquitoes, Spring 1985

2215. Washburn, Jan O., and John R. Anderson. 1991. **The case of the quick change killer: a single-celled organism turns the tables on its predators– larval mosquitoes.** Natural History 7:30-33.
Abstract: Laboratory and field studies revealed that *Lambornella clarki*, a protozoan microorganism, has the capability to transform from a free-living, potential prey form that can be eaten by filter-feeding mosquito larvae to a parasitic form that attacks, infects, and kills mosquito larvae. Larvae of the treehole mosquito, *Aedes sierrensis*, release a water-borne factor that induces morphogenesis of the free-living form of *L. clarki*, suggesting that facultative parasitism by *L. clarki* may have evolved as an antipredator strategy. In nature, this strategy can lead to extinction of larval mosquito populations in treeholes.

2216. Washburn, Jan O., John R. Anderson, and David R. Mercer. 1991. **Parasitism of newly-hatched *Aedes sierrensis* (Diptera: Culicidae) larvae by *Lambornella clarki* (Ciliophora: Tetrahymenidae) following habitat flooding.** J. Invert. Pathol. 58:67-74.
Abstract: Host-parasite interactions between the ciliate *Lambornella clarki* and its natural host, the western treehole mosquito *Aedes sierrensis*, were studied in newly-flooded treeholes in northern California between 1986 and 1989. First-instar host larvae hatched within 1 to 4 hours of flooding, while free-living trophonts of *L. clarki* appeared between 7 and 24 hours. As early as 24 hours after flooding, ciliates initiated the first parasitic cycle by forming cuticular cysts on first-instar larvae; by 64 hours, cysts were observed on larvae collected from all positive treeholes during all years. While larvae with as many as 12 cysts were observed, most supported only one cyst, and successful infections were established by the entry of a single ciliate into the host's hemocoel. Among treehole populations, the proportion of larvae with *L. clarki* cysts ranged from 2% to 100% at 48 hours, indicating that enzootics and epizootics develop rapidly in newly-flooded treeholes. Average attack rates from all holes ranged between 17.0% and 44.4%. Ciliates began entering hosts 48 to 72 hours after flooding, but some larvae escaped parasitization by molting to the second instar before ciliates penetrated the cuticle. In some treeholes, opportunistic

microorganisms entered host larvae with the invading ciliates and killed both the host and the parasite.

Cover of Science, July 12, 1991 issue, illustrating larval and pupal stages of the western treehole mosquito and the parasitic ciliate *Lambornella clarki*

2217. Washburn, Jan O., David R. Mercer, and John R. Anderson. 1991. **Regulatory role of parasites: impact on host population shifts with resource availability.** Science 253:185-188.
Abstract: Effects of infections by the ciliate *Lambornella clarki* on larval populations of its mosquito host, the western treehole mosquito *Aedes sierrensis*, were examined in laboratory and field studies. When host populations developed with sufficient food, mortality from parasites was additive and reduced the number of emerging mosquitoes. For food-limited populations, mortality was compensatory or depensatory; emerging adults were as or more abundant with higher average fitness than those from uninfected control populations. When nutrients were scarce, parasitic infections relaxed larval competition and increased per capita food by reducing host abundance. Food limitation altered larval feeding behavior, reducing horizontal transmission and subsequent mortality from parasitism.

2218. Washburn, Jan O., and Eveline U. Hartmann. 1992. **Could *Aedes albopictus* (Diptera: Culicidae) become established in California tree holes?** J. Med. Entomol. 29(6):995-1005.
Abstract: The ability of temperate zone-adapted *Aedes albopictus* to survive and complete development in California tree holes was evaluated in laboratory experiments that assessed development under simulated wet-season conditions, larval competition with *Aedes sierrensis* at different food levels, temporal survivorship of eggs stored under different humidities and temperatures, and suitability of larvae as hosts for the indigenous parasite *Lambornella clarki.* At all resources levels, *Ae. albopictus* completed development at temperatures similar to those in natural tree hole water in spring and early summer (≥16°C), but not those during the rainy winter months (4-11°C). In competition studies at 21°C, the population performance (i.e. survivorship, pupation time, and adult size) of *Ae. albopictus* at all resource levels was as good or better when larvae developed with *Ae. sirrensis* compared with when reared with only conspecifics. Egg survivorship declined with increased storage time, increased temperature, and decreased humidity; >55% of eggs hatched following 24-wk storage at 11°C with relative humidities >78%. In host suitability tests, parasitic theronts of *L. clarki* consistently attacked *Ae. albopictus* larvae at rates significantly lower than *Ae. sierrensis*. *L. clarki* that successfully invaded *Ae. albopictus* larvae failed to multiply and kill their hosts; thus, *Ae. albopictus* is not a suitable host for *L. clarki*. The protracted drying of most tree holes and low water temperatures during the rainy season will hinder but not preclude establishment of *Ae. albopictus* in California.
2219. Washburn, Jan O., David L. Woodward, Arthur E. Colwell, and John R. Anderson. 1992. **Correlation of *Aedes sierrensis* captures at human sentinels with CO_2-baited Fay-Prince and duplex cone traps.** J. Am. Mosq. Control Assoc. 8(4):389-393.
Abstract: The efficiency of the duplex-cone and Fay-Prince CO_2 traps for monitoring adult male and female *Aedes sierrensis* was evaluated at three field sites in California. The numbers of females captured by both types of traps were significantly correlated with human sentinel collections. The Fay-Prince trap captured more *Ae. sierrensis* females than the duplex cone trap and was a better tool for estimating female activity levels. There was no significant correlation between the number of males captured in Fay-Prince traps and at humans. Male numbers in duplex cone trap collections explained only 27% of the variation in the number of males collected at sentinels, suggesting that neither trap is a robust tool for estimating male activity around humans.

2220. Washburn, Jan O., and John R. Anderson. 1993. **Habitat overflow, a source of larval mortality for *Aedes sierrensis* (Diptera: Culcidae).** J. Med. Entomol. 30(4):802-804.
Abstract: In laboratory and field tests, larvae of the western tree hole mosquito *Aedes sierrensis* were flushed by rainfall from both glass containers and natural tree holes. After 7 days and an accumulated rainfall of 7.9 cm (3.1 in), between 0 and 327 *Ae. sierrensis* immatures were recovered in collection devices placed below 4 natural tree holes. Habitat overflow affected all larval stages and may be an important, but overlooked, density-independent source of larval mortality for mosquitoes developing in some water-filled containers.

Duplex cone trap baited with dry ice, being tested by UC Berkeley entomologists to capture adult western treehole mosquitoes seeking blood meals, Spring 1991

2221. Washburn, Jan O. 1995. Regulatory factors affecting larval mosquito populations in container and pool habitats: implications for biological control. J. Am. Mosq. Control Assoc. 11(2):279-283.
Abstract: Empirical studies have shown that populations of larval mosquitoes developing in ground pools are subjected to different mortality factors than populations developing in water-filled containers. In general, larvae in ground pools are limited by natural enemies whereas those in containers are limited by resource

availability. Containers also are typically smaller than ground pools and lack appreciable internal primary productivity. These physical and biological features have significant implications for successful implementation of biological control agents. Island biogeography theory suggests that container habitats will support smaller populations of fewer species compared to ground pools, implying that it may be more difficult to establish natural enemies in container habitats. The lack of primary productivity within containers may limit the number of trophic levels and reduce the likelihood of establishing and maintaining predator populations. Most importantly, larval mosquito populations in containers are regulated by competitive interactions, and mortality from natural enemies is likely to be compensatory. These habitat and population characteristics, combined with difficulties in locating and treating containers, suggest that successful control of ground pool mosquitoes using biological control agents is more feasible.

Eyeworm *Thelazia californiensis* in a black-tailed deer, February 1975

2222. Weinmann, Clarence J., William M. Longhurst, M. N. Rosen, and O. Brunetti. 1966. **Epizootiology of the eyeworm, *Thelazia californiensis* (Abstract).** P. 56 *in:* Proc. 41st Ann. Mtng. Amer. Soc. Parasitologists, San Juan, Puerto Rico.
Abstract: Geographical distribution of the eyeworm *Thelazia californiensis* is correlated with distributional patterns of suspect vectors. Data from deer and jackrabbits in California indicate that the parasite occurs mainly in foothill and mountainous regions. Seasonal changes in worm age distribution in mammals were determined at the Hopland Field Station during October-November, with peak transmission occurring in July-August. Worms require 6 to 8 weeks to reach maturity in rabbits and they live approximately a year in deer and rabbits. The prevalence of infection in various mammals at Hopland was determined. The raccoon is listed as a new host for the eyeworm. Seasonal changes in the density of suspected vectors at Hopland were determined, and evidence favoring vector infection by other than a fecal route is summarized.

2223. Weinmann, Clarence J. 1973. **Seasonality in the production of microfilariae by the deer footworm, *Wehrdikmansia cervipedis* (Abstract).** P. 27 *in:* Proc. 48th Ann. Mtng. Am. Soc. Parasitologists, Vol. 17, Toronto, Canada, Jun. 25-29.
Abstract: Post-mortem examinations of deer for footworms were made at about monthly intervals for more than a year in one study area. Adult-sized female worms were graded as: non-gravid, embryonation evident, or with uterine microfilariae. Ear skin snips were used to estimate densities of microfilariae. Embryonation was evident in a high proportion by late January and by early March the majority of females were teeming with uterine microfilariae in spite of an apparent 20:1 female:male sex ratio. Only non-gravid females were found in the fall and early winter months. Worm numbers suggested a seasonal "shut down" in reproduction rather than senescence. Skin microfilariae were most dense in spring and summer and became very sparse by late fall. The relationship of these seasonal changes to the activities of the local blackfly vector, *Prosimulium impostor*, are discussed.

2224. Weinmann, Clarence J., John R. Anderson, William M. Longhurst, and Guy E. Connolly. 1973. **Filarial worms of Columbian black-tailed deer in California. l. Observations in the vertebrate host.** J. Wildl. Dis. 9:213-220.
Abstract: An 8-year survey of filarial worm infections in black-tailed deer at the Hopland Field Station showed that the great majority of deer became infected with 3 filariids. The footworm (*Wehrdikmansia cervipedis*) and the arterial worm (*Elaeophora schneideri*) showed increased prevalence with host age, but just the opposite was seen with the abdominal worm (*Setari yehi*). The incidence of arterial worms in deer over 3 years of age was at least 78%, while 86% of such deer were infected with footworm. Most fawns were infected with the abdominal worm as were almost half the yearlings, but the parasite was relatively scarce in deer over 2 years of age.

2225. Weinmann, Clarence J. 1974. ***Hymenolepis nana* in mice: a potential model for the study of intestinal immunity (Abstract).** P. 589 *in:* Proc. 3rd Int. Congr. Parasitology, Vol. II, Facta Publication, Vienna, Austria, Munich, Germany, Aug. 25-31.
Abstract: A strong, dose-independent, long-lasting immunity to reinfection with eggs of the dwarf tapeworm *Hymenolepis nana* was consistently elicited in mice vaccinated orally with only a few, perhaps single, oncospheres attenuated through gamma irradiation. Such immunization required invasion of the intestinal wall by the eliciting parasites but little or no subsequent growth or development beyond the earliest stages was needed to render B alb C mice refractory to challenges with eggs for a year or normal oncospheres yielded levels of immunity that were substantially lower and less persistent in spite of the greater growth, differentiation, and longevity of the immunizing parasites. Observations illustrating these features are presented and their significance discussed from a general viewpoint of intestinal immunity.

2226. Weinmann, Clarence J., John R. Anderson, P. Rubtzoff, Guy E. Connolly, and William M. Longhurst. 1974. **Eyeworms and face flies in California.** Calif. Agric. 28(11):4-5.
Abstract: At the Hopland Field Station from 1964-1968, about 60% of deer and 30% of jackrabbits were infected with the eyeworm, *Thelazia californiensis*. Occasional infections were also detected in grey foxes, raccoons, and dogs. An undescribed species of *Fannia* (Diptera: Muscidae) was experimentally determined to serve as the natural vector of *T. californiensis*. The face fly, *Musca autumnalis*, did not support development of this eyeworm.

2227. Weinmann, Clarence J., and Richard Garcia. 1974. **Canine heartworm in California, with observations on *Aedes sierrensis* as a potential vector.** Calif. Vector Views 21(8):45-50.
Abstract: The mosquito-borne filarial worm, *Dirofilaria immitis*, is the causative agent of canine heartworm disease, in increasing major health problem of dogs in the U.S. and elsewhere. Until approximately 25 years ago this parasite was thought to be enzootic mainly in the southeastern states. Heartworm infection has apparently spread widely and in recent years has been recognized in California. An autochthonous case is described in a 4-year-old dog. Female mosquitoes *Aedes sierrensis* and *Ae. dorsalis* were allowed to feed on the infected dog, and the mosquitoes were subsequently examined. *Ae. sierrensis* took in 3 times as many microfilariae as *Ae. dorsalis*, while the parasite developed to third stage larvae in both species. Previous studies at Hopland indicate that *Ae. sierrensis* is an excellent host for at least one other filarial worm, *Setaria yehi*, the abdominal worm of deer. Improved means of diagnosis are needed

before the zoonotic potential of *D. immitis* as a human health problem can be assessed. However, it seems likely that *Ae. sierrensis*, because of its feeding habits, would add to the zoonotic potential. Further, this species is a very difficult mosquito to control.

2228. Weinmann, Clarence J., and Chuzaburo Shoho. 1975. **Abdominal worm infection in newborn deer (Filarioidea: Setariidae).** J. Parasitol. 61(2):317.
Abstract: An inverse relationship between host age and infection with the abdominal worm *Setaria yehi* was found in a recent survey of filarial worms in black-tailed deer (*Odocoileus hemionus columbianus*) in northern California. Fawns were commonly infected (at least 67%), as well as yearlings (43%), but this mosquito-borne parasite was relatively scarce in older deer (11%). Older infected animals were often debilitated from other causes or were from areas where mosquito transmission was minimal, suggesting that acquired immunity, rather than age per se, was mainly responsible for the pattern.

2229. Weinmann, Clarence J., Kevin Murphy, John R. Anderson, James C. DeMartini, William M. Longhurst, and Guy E. Connolly. 1979. **Seasonal prevalence, pathology and transmission of the quail heartworm, *Splendidofilaria californiensis,* in northern California.** Can. J. Zool. 57(10):1871-1877.
Abstract: This study presents observations on the prevalence and pathology of the quail heartworm, *Splendidofilaria californiensis*, in a northern California study area and on the blood-sucking arthropods associated with valley quail during the transmission season. At Hopland, heartworm transmission occurred through the summer months. Observations in laboratory-reared California valley quail infested while serving as sentinels indicated a prepatent period of several months and a patent period lasting 18-21 months. Examination of 111 wild quail revealed *S. californiesis* in 76% of adults and in 44% of juveniles. Mature parasites were encapsulated in the wall of the aorta near its origin, resulting in partial occlusion of its lumen and related pathologic changes. Infections in adult birds, but not in juveniles, appeared heavier in fall than in spring and there were indications of superimposed infections in the former. Extensive examination and studies of ectoparasites associated with valley quail were conducted. By process of elimination, it was concluded that the biting fly *Culicoides multidentatus* is the principal, if not the only, vector of quail heartworm at the study area.

2230. Westrom, Dale R. 1975. **The population dynamics and distribution of ectoparasites on black-tailed deer (*Odocoileus hemionus columbianus*) in Mendocino County, California.** Ph.D. Dissertation, Univ. Calif. Berkeley. 184 pp.
***Abstract*:** The population dynamics and distribution of ectoparasites on black-tailed deer (*Odocoileus hemionus columbianus*) were studied at the Hopland Field Station from 1970 to 1973. A modified digestion technique was used to quantitatively collect ectoparasite populations on deer. Infestations were compared on the basis of the host's age, sex, habitat, and season of collection. The distribution of each ectoparasite species on the deer was determined by dividing the host into 6 regions. Over 200,000 ectoparasites were collected from 71 black-tailed deer, with a mean of 2,818 individuals per deer and a range of 81 to 23,443. The ectoparasite species collected, in order of their prevalence (with the number of deer positive in parentheses), were: *Lipoptena depressa* (71), *Pulex irritans* (70), *Neolipoptena ferrisi* (60), *Dermacentor occidentalis* (59), *Solenopotes ferrisi* (51), *Ixodes pacificus* (47), *Tricholipeurus parallelus* (37), *Tricholipeurus lipeuroides* (30), *Ornithodoros coriaceus* (23), *Dermacentor albipictus* (19), *Bovicola tibialis* (3), *Haemaphysalis leporispalustris* (1), and *Opisodasys keeni* (1). The last 3 species represent the first records from black-tailed deer. *Bovicola tibialis* was acquired by the black-tailed deer from fallow deer, *Dama dama*, introduced into the study area in 1965. Mallophaga were the most abundant ectoparasites (137,521 specimens) followed by *L. depressa* (30,091), *S. ferrisi* (19,858), *O. coriaceus* (2,823), *D. occidentalis* (2,112), *N. ferrisi* (1,665), *P. irritans* (1,495), *I. pacificus* (1,336), and *D. albipictus* (1,184). Two species, *O. keeni* and *H. leporispalustris*, were each represented by a single specimen and were considered accidental parasites. The most notable differences in prevalence and abundance of ectoparasites were observed on deer from different seasons. There was a significantly higher prevalence and abundance of *O. coriaceus* and *N. ferrisi* in the summer, of Mallophaga in the winter and spring, and of *D. albipictus* in fall and winter than other seasons. The sex of the host had no appreciable influence on the prevalence or abundance of any ectoparasite species except *I. pacificus* which infested a significantly higher proportion of males than females. Ectoparasite infestations on deer of different ages were similar except for *S. ferrisi*, which was most abundant on fawns, and *N. ferrisi* which was most abundant and prevalent on deer older than one year. Deer from the chaparral had a higher prevalence of *O. coriaceus* and a higher abundance of *O. coriaceus* and *D. occidentalis* than deer from the oak woodland. Mallophaga were more prevalent and abundant on oak woodland deer than deer from other habitats. Sex ratios were calculated for 9 species of ectoparasites and 7 differed significantly from a 50:50 ratio. The sex ratios of several species were influenced by the season of collection and their location on the host. The proportion of larvae, nymphs, and adults was determined for each tick species. *D. occidentalis* yielded the largest percentage of adults and *O. coriaceus* the fewest. The distribution of each ectoparasite species on the host was determined and, in some instances, compared on a seasonal basis. Only one species failed to exhibit a preference for one or more of the 6 body regions examined. Factors potentially influencing the distribution of the various species were analyzed and discussed. The developmental period of *L. depressa* and *N. ferrisi* was studied in the field and laboratory to help interpret the collection data. The morphology of the claws and mouthparts of the two species were compared to provide clues to their disparate distributions on the deer. The digestion technique was evaluated to determine its efficiency in collecting ectoparasites from dead hosts and its accuracy in revealing distributions of arthropods on the surface of deer. An analysis of the emigration of ectoparasites from dead ground squirrels (in lieu of deer) was conducted to help interpret the deer ectoparasite data. The results of this study suggest that systematic sampling of just one area of a host, or of hosts from only one season, would produce misleading data on the sex ratio, prevalence, and abundance of many ectoparasites of black-tailed deer.


Guy E. Connolly

Twin 3-year-old fallow bucks in 'Parasite Pens', June 1971

2231. Westrom, Dale R., Bernard C. Nelson, and Guy E. Connolly. 1976. **Transfer of *Bovicola tibialis* (Piaget) (Mallophaga: Trichodectidae) from the introduced fallow deer to the Columbian black-tailed deer in California.** J. Med. Entomol.

13(2):169-173.
Abstract: *Bovicola tibialis*, a louse parasite of the European fallow deer (*Dama dama*), was found infesting 3 Columbian black-tailed deer (*Odocoileus hemionus*) at Hopland Field Station. In 1965, fallow deer (*Dama dama*) were introduced onto the station and were kept in an experimental pasture with black-tailed deer. Transfer of lice presumably occurred by direct contact between the 2 species of deer as they congregated at a feeder within the pasture, and subsequent transfers among black-tailed deer accounted for the infestations reported herein. As no males were found among the 18,148 specimens collected, we suggest that parthenogenetic reproduction occurs in *B. tibialis.*

2232. Westrom, Dale R., and John R. Anderson. 1983. **The population dynamics of *Solenopotes ferrisi* (Anoplura: Linognathidae) on the Columbian black-tailed deer *Odocoileus hemionus columbianus*.** Can. J. Zool. 61(9):2060-2063.
Abstract: A digestion technique was used to quantitatively analyze the absolute sucking louse population on 71 Columbian black-tailed deer from Northern California over a 3-year period. Infestations were compared on the basis of host anatomy, age, sex, habitat, and season of collection. The distribution of lice was determined by dividing the host into 6 regions. A total of 19,598 Anoplura (all *Solenopotes ferrisi*) was collected from 51 of 71 deer sampled with a mean infestation of 389 lice per infected deer and a range of 1 to 3,968. These prevalence and abundance figures are much higher that previously recorded for *Solenopotes* on black-tailed deer. Lice were more abundant on fawns and on deer shot in the winter and spring. Lice exhibited a marked preference for the anterior regions of hosts, particularly when few lice were present.


Guy E. Connolly
UC Berkeley graduate student Dale Westrom examines deer fawn for ectoparasites, September 1973

2233. Westrom, Dale R., Robert S. Lane, and John R. Anderson. 1985. ***Ixodes pacificus* (Acari: Ixodidae): population dynamics and distribution on Columbian black-tailed deer (*Odocoileus hemionus columbianus*).** J. Med. Entomol. 22(5):507-511.
Abstract: The absolute population density and spatial distribution of the ixodid tick *Ixodes pacificus* were determined on Columbian black-tailed deer collected over a 3-year period in northern California. Tick abundance was compared as to season and age, anatomy, habitat, and sex of deer. Spatial distribution was analyzed by dividing the deer hide into 6 regions and processing each section separately. In total, 1,336 *I. pacificus* were collected from 47 (66%) of 71 deer examined. Of these, 94.6% were adults and the remainder larvae and nymphs. The number of ticks averaged 18.8 per deer and the intensity (= mean number of ticks per infested host) was 28.4. The prevalence of ticks on female deer (79%) was greater in fall and winter than in spring and summer. Males constituted 54% of the adults; more males than females occurred on deer in winter than in other seasons and on the posterior dorsum than on other body regions. Overall, 80% of the ticks found occupied the anterior and posterior venters. Nearly 90% of larvae and nymphs were found in spring. Larvae preferred the ventral regions of the body, and nymphs the venter and head.

2234. Westrom, Dale R., and John R. Anderson. 1992. **The distribution and seasonal abundance of deer keds (Diptera: Hippoboscidae) on Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in northern California.** Bull. Soc. Vector Ecol. 17(1):57-69.
Abstract: The seasonal abundance and distribution of deer keds (*Lipoptena depressa* and *Neolipoptena ferrisi*) on Columbian black-tailed deer (*Odocoileus hemionus columbianus*) in northern California were studied over a 3-year period. A digestion technique enabled quantitative collection of ectoparasites from the hide of the entire host. Absolute population densities of deer keds were compared on the basis of host anatomy, age, and sex and on the season and habitat of collection. *Lipoptena depressa* was present on all 71 deer examined; a total of 30,091 specimens was collected with mean infestation of 424 keds per infested deer (range 21 to 1,563). Seasonal abundance data showed, for the first time, that this was a bivoltine species with populations on deer peaking in midsummer and early winter. *Neolipoptena ferrisi* was found on 60 of 71 deer with a significantly lower prevalence on younger deer and deer collected in the spring. This univoltine species reached its greatest density on deer during the summer. The 60 infested animals yielded 3,660 *N. ferrisi* with a mean infestation of 61 keds per deer (range 1 to 481). Alate (winged) forms of both species were far less abundant on deer than were the apterous forms. Most *L. depressa* (64%) occurred on the posterior regions of the deer with only 1.5 percent on the head. Conversely, most *N. ferrisi* were found on the head, with only 5% collected from the posterior regions. Factors potentially influencing the disparate distributions of the 2 species are analyzed and discussed.

2235. Willadsen, Claus M. 1974. ***Toxoplasma gondii* infection in sheep: literature review and seroepidemiological observations.** Master of Preventive Veterinary Med., Univ. Calif. Davis. 63 pp. + appendix.
Abstract: The literature on the natural history of *Toxoplasma gondii* is reviewed with special emphasis on ovine *Toxoplasma* infections. The results of a serological survey for antibodies to *Toxoplasma gondii* in sheep from California, Nevada, Oregon, and Idaho are presented. Serological results, determined by means of a microtiter modification of the indirect hemagglutination test, are analyzed together with information obtained from sheep owners by questionnaire. Among 1,206 blood samples collected from sheep at the time of slaughter at the Armour Meat Packing Co., Dixon, CA, 94 samples were seropositive giving an overall prevalence rate of 8%. Among sheep coming from outside California prevalence rate of antibodies to *Toxoplasma* of 16% was found compared to a prevalence rate of 4% among sheep coming inside California. Among sheep slaughtered between the end of December 1973 and the end of March 1974, a prevalence rate of 13% was found, while sheep slaughtered during April and May 1974 showed a prevalence rate of 1%. Lambs born during May 1973 showed a higher prevalence rate of antibodies to *Toxoplasma* (23%) than lambs born from October through December 1974 (3%). The prevalence rate was also found to be higher among lambs that had spent at least 1 month before slaughter under feedlot conditions than among lambs that were shipped to slaughter directly from range (12% versus 4%). Among 405 blood samples collected from sheep with ages ranging from a few months to 11 years and belonging to the Hopland Field Station, an increasing prevalence of antibodies to *Toxoplasma* with increasing age of sheep was found. The results from this study seem to indicate that the domestic cat plays a minor role in the

epidemiology of ovine toxoplasmosis in this area: the prevalence rate among sheep raised on premises where the owner had reported the absence of cats was 7% compared to a prevalence rate of 8% among sheep raised on premises where cats reportedly were present. The results of the surveys are discussed and compared with observations of other authors. The possible reasons for the apparent absence of ovine abortion and stillbirth due to *Toxoplasma* infection in the area are briefly mentioned.

2236. Wood, John R., Vincent H. Resh, and Eileen M. McEwan. 1982. **Egg masses of nearctic sericostomatid caddisfly genera (Trichoptera).** Ann. Entomol. Soc. Am. 75(4):430-434.
Abstract: The unique egg masses of three North American sericostomatid caddisfly genera are described and illustrated. *Agarodes* forms a tetrahedra egg mass; *Fattigia* and *Gumaga* produce egg masses with 2 subequal halves constricted at the middle and folded into a "V" and a "U" shape, respectively. Under certain circumstances, *Gumaga* can produce a spherical egg mass. These egg masses support the view that *Fattigia* and *Agarodes* should be considered separate genera.

2237. Yee, Wee L., and John R. Anderson. 1992. **Comparison of dispersal patterns of gravid and *Lambornella clarki*-infected *Aedes sierrensis* (Ludlow) inside a field cage.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 68-70.
Abstract: The protozoan parasite *Lambornella clarki* can cause significant mortality to larval populations of the western treehole mosquito *Aedes sierrensis* under certain conditions. Some larvae survive infection, pupate, and emerge as infected adults. In order for treeholes to be colonized by the parasite, adult mosquitoes must disperse and then deposit the parasites into them. Because treeholes are often hard to find, it would be useful to know if infected mosquitoes are as likely to find treeholes as are gravid mosquitoes. If infected mosquitoes could be used as the agents for inoculating the treeholes with parasites, they could aid in this potential method of biological control. Evidence suggests that once a treehole is positive for the parasite, it tends to remain so year after year. The objective of this study was to determine whether infected female mosquitoes disperse to artificial treeholes in a manner similar to gravid mosquitoes. Studies were conducted in a large field cage at Hopland, which held ovitraps (plastic cups filled with treehole water and a wooden tongue depressor, placed within a one-gallon black paper can). Preliminary results suggest several conclusions, as follows. Gravid female mosquitoes do not always lay eggs in the nearest or most readily accessible oviposition sites. The strong correlation between activity as measured by mosquito presence inside ovitraps and temperature during the day suggest either that 1) mosquitoes oviposit during the hottest part of the day, or 2) that mosquitoes were most likely to seek water during the hottest part of the day, or both. Mosquitoes did not rest in traps during early morning or just before dark. For whatever reason, most of the mosquitoes which entered to rest or oviposit inside the ovitraps left within a few hours; only a few stayed more than 8 hours. Mosquitoes preferred traps in the shade, which were the ones in the corners or along the sides of the cage. Egg distribution may reflect the possibility that mosquitoes flew into the screen on the sides of the cage, and then down into the ovitraps. In nature, treeholes surrounded by or situated amongst dense vegetation may be more attractive than ones isolated by themselves or in the open. The one test comparing infected females vs. gravid females revealed only that under cold, wet conditions they behaved similarly. None of the mosquitoes in this test showed much activity and did not disperse much from the release point.

2238. Yee, Wee L. 1993. **Comparison of dispersal patterns of gravid and *Lambornella clarki*-infected *Aedes sierrensis* (Ludlow) inside field cages.** Mosquito Control Research Ann. Rep., Div. Agric. & Nat. Resour., Univ. Calif., pp. 54-57.
Abstract: The western treehole mosquito, *Aedes sierrensis*, develops inside treeholes after rains in late fall and winter, pupates in late winter and spring, and emerges as an adult in spring and summer. Eggs are laid inside treeholes during spring, summer, and sometimes in the fall. Although laboratory studies of oviposition site preferences and egg hatching rates of this mosquito have been reported, no information exists on the temporal and spatial patterns of egg dispersal behavior under field conditions. The objectives of this study were 1) to describe the temporal and spatial patterns of egg dispersal by gravid females, and 2) to determine the tendencies of gravid and mosquitoes infected by the protozoan parasite *Lambornella clarki* to fly to artificial treeholes under semi-natural conditions. Gravid females were attracted to oviposition sites when the temperatures were very high, and certain traps were favored based on their locations– possibly because they were in the shade, rather than because of their quality. These results have important implications for the ecology of *Ae. sierrensis*, since they suggest that treeholes in shady situations might be the most favored and consequently have the highest interspecific competition. The ability of *L. clarki* to cause *Ae. sierrensis* to fly to and deposit parasites into treeholes suggest that treehole-seeking tendencies themselves may not explain the lower occurrence of parasite- vs. egg-positive treeholes. Infected females were nearly as efficient in depositing parasites into traps as gravid females were in depositing eggs into the traps, even if the lower trap visitation rates by infected females suggest a reduced attractancy to fly to and then stay in them.

2239. Yee, Wee L., and John R. Anderson. 1995. **Trapping black flies (Diptera: Simuliidae) in northern California. II. Testing visual cues used in attraction to CO_2-baited animal head models.** J. Vector Ecol. 20(1):26-39.
Abstract: Studies were conducted in northern California from 1989 to 1992 to determine what visual cues influence black flies to land on CO_2-baited animal head models. Significantly higher numbers of *Simulium argus*, *S. vittatum*, and *S. virgatum* were collected on the ears than on the heads, but neither *S. argus* nor *S. vittatum* showed a very clear preference for ears placed in horizontal versus vertical orientations. However, *S. virgatum* landed in significantly higher numbers on horizontally-oriented ears. Black flies did not preferentially land on ears of short (1.23 m) versus tall (1.74 m) models. Brown ears on almond-colored heads collected the highest number of *S. argus* when compared with almond-colored ears on brown heads, brown on brown, and almond on almond. There was no significant difference in the numbers of black flies caught on small (surface area = 45 cm^2), medium (164 cm^2), or large (228 cm^2) ears. More *S. argus* and *S. vittatum* landed on the edges and tips than on other ear regions, more *S. argus* landed on the front than on the back of the ears, and more *S. argus* landed on the anterior part of the head ("muzzle") than on other head regions (except the ears).

2240. Yee, W. L., and John R. Anderson. 1995. **Tethered flight capabilities and survival of *Lambornella clarki*-infected, blood-fed, and gravid *Aedes sierrensis* (Diptera: Culicidae).** J. Med. Entomol. 32(2):153-160.
Abstract: Flight capabilities and survival of *Lambornella clarki*-infected, control, blood-fed, and gravid *Aedes sierrensis* were monitored using a tethered flight mill system and by recording deaths at various times after initiation of these tests. Flight capabilities of infected and control males as measured by total number of flights, total time spent flying, total distance flown, average flight speed, and percentage time flying were similar. Flight capabilities of females with parasites, with fresh blood meals, and with fully developed eggs did not differ significantly. Although flight capabilities did not differ significantly, infected males died earlier than control males. For females, blooded individuals lived longest, followed by controls, and then gravid and infected individuals. These results and results of

glycogen analyses of mosquito thoraces indicated that the parasite primarily affected resources needed by the mosquito for survival and not those for flight.

2241. Yee, W. L., and John R. Anderson. 1995. **Free flight of *Lambornella clarki*-infected, blood-fed, and gravid *Aedes sierrensis* (Diptera: Culicidae).** J. Med. Entomol. 32(4):407-412.
Abstract: Total flight times and flight numbers of *Lambornella clarki*-infected and uninfected nonblood-fed (control), blooded, and gravid western treehole mosquitoes, *Aedes sierrensis*, were monitored in laboratory experiments using a free-flight acoustical system. Mean flight time and number of males were not affected by *L. clarki* infection, but mean flight time of infected females was significantly less than those of control and gravid females. Flight numbers of infected and control females did not differ significantly. Blood feeding initially suppressed an increase in flight that corresponded to increased parasite presence inside the ovaries in young, but not older, females.

2242. Zingg, Barbara C., Richard N. Brown, Robert S. Lane, and Rance B. LeFebvre. 1993. **Genetic diversity among *Borrelia burgdorferi* isolates from wood rats and kangaroo rats in California.** J. Clin. Microbio. 31(12):3109-3114.
Abstract: Twenty-nine *Borrelia burgdorferi* isolates, obtained from dusky-footed wood rats (*Neotoma fuscipes*) and California kangaroo rats (*Dipodomys californicus*) in California, were analyzed genetically. Chromosomal DNA was examined by restriction endonuclease analysis (REA) and gene probe restriction fragment length polymorphism. Pulsed-field gel electrophoresis was used to analyze the plasmid profiles of the isolates. REA, the method with the greatest discrimination, disclosed 24 distinct restriction patterns among the 29 isolates. These restriction patterns were sorted into 4 restriction fragment length polymorphism groups on the basis of their gene hybridization patterns. Results of the REA and plasmid profile analysis supported this grouping. The degree of genetic diversity among Californian isolates demonstrated by our findings is greater than that previously reported among other groups of North American isolates and is similar or greater than the diversity reported among European isolates.

PLANT SCIENCE & ECOLOGY

Robert H. Schmidt

3001. Adams, David R., and Steven R. Radosevich. 1978. **Regulation of chamise shoot growth.** Am. J. Bot. 65(3):320-325.
***Abstract*:** Nutritional, hormonal, and environmental control of chamise (*Adenostoma fasciculatum*) shoot growth was investigated. *In vitro* culture of root tips demonstrated that 0.18 M sucrose was required for optimum apical growth. Cytokinin (benzyladenine) promoted shoot growth at otherwise growth-limiting sucrose concentrations and induced uptake of sucrose from the basal medium. Abscisic acid inhibited growth of cultured shoot tips induced by high sucrose concentration or cytokinin. In the field, inhibition of shoot growth was a function of water stress. These studies indicated that the effects of water stress on chamise shoot growth may be mediated by changes in carbohydrate, cytokinin, or growth inhibitor levels at the shoot apex.

3002. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, N. K. McDougald, and James W. Bartolome. 1987. **Enemies of white oak regeneration in California.** Pp. 459-462 *in:* Proc. Symp. Multiple-Use Manage. of Calif. Hardwood Resources, (T. R. Plumb and N. H. Pillsbury, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Gen. Tech. Rep. PSW-100.
Abstract: In 1985-86, a series of artificial oak regeneration studies, using blue oak and valley oak, was started in 6 counties: Yuba, Mendocino, Contra Costa, San Benito, Madera, and San Luis Obispo. Acorns planted directly in field plots, and nursery transplants (2-month old and 1-year old stock) were used, but each plant material was not planted at all sites. Acorns were planted in November and transplants in winter. Each site was as flat as the terrain permitted to minimize the influence of slope exposure. All work was conducted inside deer-proof exclosures and away from canopy effects on oak-grassland range supporting mature stands of the trees. Seedling emergence and survival studies indicated oak regeneration was affected by competition from spring and summer weeds, small mammals, and insects. Weed control in late spring and summer served to reduce moisture stress, and also discouraged pocket gophers (*Thomomys* spp.) by removing herbaceous food sources. Regeneration on some study sites was impossible without protection from all described competitors. For field transplants, 2-month-old nursery stock appears superior to 1-year-old stock. Younger material is cheaper to grow and easier to transport and plant.

3003. Adams, Theodore E., P. B. Sands, and W. H. Weitkamp. 1988. **Artificial regeneration of blue and valley oak in California.** Range Sci. Rep. 16, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 9 pp.
***Abstract*:** Several species of white oak are not regenerating well in many areas of California. Suspected elements of poor valley oak (*Quercus lobata*) and blue oak (*Q. douglasii*) regeneration are being studied in three regions using artificial regeneration techniques. Plantings of acorns and nursery stock have been made within deer-proof enclosures to examine the impacts of weed competition, fertilization, and small mammals and insects. Results suggest weed control and protection from small mammals and insects will be necessary for successful artificial regeneration of blue and valley oak in many areas of the state.

3004. Adams, Theodore E., P. B. Sands, and W. H. Weitkamp. 1988. **Artificial regeneration of white oaks in California (Abstract).** P. 185 *in:* Abstracts, 41st Ann. Mtng., Soc. Range Manage., Corpus Christi, TX.
***Abstract*:** To study suspected elements of poor valley oak (*Quercus lobata*) and blue oak (*Q. douglasii*) regeneration in California, acorns and nursery stock of these species were planted in three regions during the 1985-1986 growing season (October 1 to September 30). Factors investigated include: herbaceous competition, fertility, and depredation by small mammals and insects. Each plant material was planted in randomized complete blocks within deer-proof exclosures and away from canopy effects on oak-grassland range supporting mature stands of the trees. Regions represented are the north coast (Mendocino County), south-central coast (San Luis Obispo County), and the eastern Sacramento Valley north of San Francisco Bay (Yuba County). Results suggest weed competition is a major cause of the poor emergence and survival of seedlings developing from field-planted acorns and survival of transplanted nursery stock. These problems are aggravated by the use of a slow release fertilizer. Small mammals and insects are responsible for additional mortality. Artificial regeneration of the two species may require intensive culture and management.


Robert H. Schmidt

UC Davis wildland ecology Extension specialist Ted Adams examines young oak trees in a test of methods to improve seedling survival, 1989

3005. Adams, Theodore E., P. B. Sands, and W. H. Weitkamp. 1989. **Oak regeneration by artificial means.** Oaks 'n' Folks 4(1):6.
Abstract: Briefly describes studies on regeneration of blue oak and valley oak in 6 counties in California, employing both acorns and nursery stock planted within fenced exclosures that exclude deer and livestock. Weed control increases emergence and survival by reducing competition from soil moisture. Above-ground screens may be needed to protect foliage from insects and rodents. Pocket gophers are a particular problem, and their control with poisoned grain baits may be necessary to prevent root damage. Weed control to eliminate tap-rooted forbs such as filaree and mustard can help discourage pocket gopher activity in the vicinity. In our plots, during the third growing season some seedlings are now 2-3 feet tall; with a few more years of protection, such plants should be well enough established to reach maturity.

3006. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and N. K. McDougald. 1991. **Blue and valley oak seedling establishment on California's hardwood rangelands.** Pp. 41-47 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage. (R. B. Standiford tech. coord.), Davis, CA. USDA For. Serv., Gen. Tech. Rep. PSW-126.
Abstract: Factors contributing to poor establishment of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) in California oak-grassland savannas were studied in a series of acorn seeding experiments initiated in 1985. Exclusion of large herbivores permitted examination of herbaceous interference and small mammal

and insect depredation. Herbaceous interference was the most important factor. Average emergence in all blue oak seedings with and without weed control was 45% and 29%, respectively. The respective values for all valley oak seedings were 60% and 46%. Average first year survival, expressed as a percentage of acorns planted, was significantly improved by elimination of herbs in both blue oak (30% vs. 11%) and valley oak (45% vs. 25%) seedings. Limited data suggests the differential in survival is maintained over time as overall survival declines. With few exceptions, the addition of screen protection to discourage predation significantly enhanced survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution. Interaction between herbaceous control and protection appears to develop with time.

3007. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and N. K. McDougald. 1991. **Blue oak seedling regeneration on California rangeland.** Pp. 521-522 *in:* Proc. Soc. Amer. Foresters Nat. Convention: Pacific Rim Forestry– Bridging the World, San Francisco, CA. SAF, Bethesda, MD, Aug. 4-7.
Abstract: Poor regeneration of blue oak (*Quercus douglasii*) in many locations on California hardwood rangelands has encouraged examination of factors suspected to be responsible so that management strategies for enhancement of regeneration can be developed. To examine selected factors, exclusive of large herbivore impacts, a series of acorn seeding experiments was initiated in 1985 in 6 counties on typical blue oak sites. Factorial experiments organized in a randomized complete block design were used to examine weed competition and predation by insects and small mammals in a split plot design. Weed control for reduction of moisture stress was the most important factor examined. Emergence was significantly improved by weed control in over 70% of seedlings. Average first year survival, expressed as a percentage of acorns planted, was significantly improved with weed control, 30% vs. 11%. Limited data suggests the differential in survival remains consistent over time as overall survival declines. With few exceptions, the addition of screen protection to discourage predation significantly enhanced survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution.

3008. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and N. K. McDougald. 1992. **Blue oak seedling regeneration on California rangelands.** Pp. 67-71 *in:* Proc. IV Int. Rangeland Congr., Montpellier, France.
Abstract: Poor regeneration of blue oak (*Quercus douglasii*) in many locations on California hardwood rangelands has encouraged examination of factors suspected to be responsible so that management strategies for enhancement of regeneration can be developed. To examine selected factors, exclusive of large herbivore impacts, a series of acorn seeding experiments was initiated in 1985 in 6 counties on typical blue oak sites. Factorial experiments organized in a randomized complete block design were used. In 1985, the design included only examination of weed competition. Both weed competition and predation by insects and small mammals were examined beginning in 1987 in a split plot design. Rainfall and edaphic factors were used to help interpret measures of seedling emergence, survival, and growth. Weed control for reduction of moisture stress was the most important factor examined. Emergence was significantly improved by weed control in over 70% of seedlings. Average first year survival, expressed as a percentage of acorns planted, was significantly improved with weed control, 30% vs. 11%. Limited data suggests the differential in survival remains consistent over time as overall survival declines. With few exceptions, the addition of screen protection to discourage predation significantly enhanced survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution. Interaction between weed control and protection appears to be site specific.

3009. Adams, Theodore E. 1992. **Competition control strategies for the artificial regeneration of California blue oak.** Oaks 'n' Folks 7(2):5-6.
Abstract: Reduced precipitation and moisture competition from weeds are known to reduce seedling establishment in oak seedlings in California. Beginning in 1988, 3 successive annual dryland plantings of 2-month-old blue oak nursery stock were made in late winter at the Hopland and Sierra Foothill Field Stations. To control weeds, a one-time application of a herbicide mixture of atrazine and oxyfluorfen was compared to the installation of plastic mulch mats, both porous and impervious. The area treated around each seedling was 16 ft^2. Seedlings receiving weed control had 60% better survival than untreated seedlings, but there was no difference among weed control treatments. Type of weed treatment did, however, influence seedling growth: seedlings mulched with impervious polyethylene grew 50% more than those receiving a single herbicide application. Because there were no height differences between seedlings receiving a single herbicide treatment and untreated controls, this suggests the value of a persistent weed suppression strategy. Material costs for an impervious polyethylene mat was about $0.70 per seedling, while the herbicide application cost was less than $0.02 per seedling.

3010. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and N. K. McDougald. 1992. **Oak seedling establishment in California oak woodlands (Poster Presentation).** Pp. 137-140 *in:* Ecol. and Manage. of Oak and Assoc. Woodlands: Perspectives in the Southwestern U.S. and Northern Mexico (P. F. Ffolliott, et al., tech. coords.), Sierra Vista, AZ. USDA For. Serv., Gen. Tech. Rep. RM-218.
Abstract: Factors contributing to poor establishment of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) in California oak woodlands were studied in a series of acorn seeding experiments initiated in 1985. Exclusion of large herbivores permitted examination of herbaceous interference and small mammal and insect depredation. Herbaceous interference was the most important factor. Control improved emergence in nearly 80% of blue oak seedings and in 40% of valley oak seedings. Survival, expressed as a percentage of acorns planted, was significantly improved by elimination of herbs in seedings of both blue oak and valley oak. Limited data suggest that differential survival is maintained over time as overall survival declines. With few exceptions, the addition of screen protection to discourage predation significantly enhanced survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution. Interaction between herbaceous control and protection appears to develop with time.

3011. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and N. K. McDougald. 1992. **Oak seedling establishment on California rangelands.** J. Range Manage. 45(1):93-98.
Abstract: Factors responsible for poor recruitment of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) need to be determined on California hardwoods rangelands so that management strategies for enhancement of recruitment can be developed. To examine selected factors, exclusive of large herbivore impacts, a series of acorn seeding experiments was initiated in 1985 in 6 counties on representative sites. At each site, the experimental treatments were the factorial combination of herbs vs. no herbs and screen protection vs. no protection. The experimental design was four randomized complete blocks of the herb treatments with each main plot split for the two levels of protection. Rainfall and edaphic factors were used to help interpret measures of seedling emergence, survival, and growth. Herbaceous plant control for reduction of moisture stress was the most important factor examined. Emergence was significantly improved by control in nearly 80% of blue oak seedings

and 33% in valley oak seedings. Average first year survival, expressed as a percent of acorns sown, was significantly improved with control in seedings of both blue oak (33% vs. 18%) and valley oak (45% vs. 21%). Limited data suggest the difference in survival remains consistent over time as overall survival declines. With few exceptions, the additions of screen protection discouraged predation and significantly enhanced survival and growth. Window screen cages also may have contributed an unmeasured shade effect.

3012. Adams, Theodore E. 1994. **Techniques to enhance oak regeneration studied.** Oaks 'n' Folks 9(1):4-6.
Abstract: Trials to examine factors suspected of contributing to poor seedling regeneration of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) were initiated in 1985 at 6 locations statewide, including Hopland. Weed control significantly increases seedling emergence and subsequent survival. Addition of window screen cages to protect seedlings from predation enhances survival and growth in almost all cases. In 1992, over 80% of spring seedling mortality at Hopland was caused by rodents; about 2/3 was due to voles (*Microtus californicus*) with the remainder caused by gophers. A weed treatment using an impervious polyethylene barrier appeared to aggravate the problem by providing cover for rodents and exposing the younger seedlings to greater damage. Failure to control weeds attracted rodents, particularly voles, leading to greater damage. Mulch mats promoted significantly better growth than herbicide application. A single herbicide application at planting was as effective in promoting survival as any other treatment, and least costly. Use of 2- to 3-month-old nursery stock provided higher survival compared with direct-seeded acorns in blue oak. The value of window screen cages to protect seedlings from predation and enhance growth was clearly demonstrated and is recommended for blue oak plantings on rangeland.

3013. Adams, Theodore E., W. H. Weitkamp, N. K. McDougald, and M. E. Stanley. 1994. **Oak seedling establishment by artificial regeneration on California's rangelands (Abstract).** P. 2 *in:* Abstracts, 47th Ann. Mtng., Soc. Range Manage., Colorado Springs, CO, Feb. 13-18.
Abstract: Examination of factors suspected of contributing to poor seedling regeneration of blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) was initiated in 1985 at 6 locations statewide. Factorial seeding experiments organized in a replicated, split-plot design were used. Weed control for reduction of moisture stress has been the most important factor examined. Average emergence in all blue oak seedlings with and without weed control was 45% and 29%, respectively. The respective values for all valley oak seedings were 60% and 46%. Values for the 2 species are different ($P \leq 0.05$). Average first year survival, expressed as a percentage of acorns planted, was significantly ($P \leq 0.05$) improved with weed control in seedings of both blue oak (34% vs. 12%) and valley oak (45% vs. 29%). Data collected to date shows that the survival differential increases with time as overall survival declines. The addition of screen protection to discourage herbivory by small mammals and insects enhances both survival and growth. Shade provided by window screen cages is suspected of making an unmeasured positive contribution. Interaction between weed control and protection developed with time. Supplemental studies compared survival between directly seeded acorns and 2- to 3-month-old nursery stock and evaluated the efficacy of alternative weed control strategies. In these replicated trials, survival of nursery stock was superior ($P \leq 0.05$) where protection from rodent herbivory was successful. Efficacy of weed control strategies showed no difference in survival between a onetime application of herbicide and use of synthetic mulch mats, but mulch mats appeared to aggravate damage from burrowing rodents. However, compared with herbicide use impervious polyethylene significantly ($P \leq 0.01$) enhanced height.

3014. Adams, Theodore E., and Neil K. McDougald. 1995. **Planted blue oaks may need help to survive in southern Sierras.** Calif. Agric. 49(5):13-17.
Abstract: Competition from annual herbaceous plants is one of many factors inhibiting establishment of blue oaks in California. Other factors include drought and large and small mammal depredation; gophers are a particularly serious threat to the seedling's emergence and survival. To measure the impact of these and other factors, a series of studies compared the emergence and survival of directly seeded acorns and 2-month-old nursery stock. Results show that careful site selection, control of competition, and protection from mammal predators may all be needed to promote success of restocking programs in California rangelands.

Research associate Chuck Vaughn assists local students to plant native oaks, Spring 1995

3015. Adams, Theodore E., P. B. Sands, and W. H. Weitkamp. 1995. **Oak seedling recruitment through artificial regeneration on California rangelands.** Pp. 1-2 *in:* Rangelands in a sustainable biosphere. Proc. 5th Int. Rangeland Congress, Vol. 1 (N. E. West, ed.), Salt Lake City, UT. Soc. for Range Manage., Denver, CO.
Abstract: Blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) seedling recruitment on California rangeland is poor in many locations. Using artificial regeneration techniques, research is documenting the contribution to mortality of herbaceous plant interference and rodent and insect herbivory where large herbivores are excluded. Success of natural oak recruitment and restocking programs may be severely limited unless herbaceous plant control and protection against rodents and insects is considered part of management.

3016. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, N. K. McDougald, and M. E. Stanley. 1996. **Rodent herbivory complicates oak recruitment on California rangelands (Abstract).** *In:* Abstracts, 49th Ann. Mtng., Soc. Range Manage., Wichita, KS.
Abstract: Poor recruitment in many stands of native blue and valley oaks growing in California's rangelands has encouraged study of associated problems and evaluation of strategies that may enhance restoration and mitigation efforts. Our studies have employed 2 approaches: 1) replicated acorn seeding trials to examine the effects of herbaceous plant interference and rodent herbivory, and 2) use of 2-month-old nursery stock in companion trials to compare survival and growth of seedlings developing from the 2 classes of plant material growing in weed free conditions with and without rodent protection. Competition from annual herbaceous plants has been found to severely limit emergence and survival of blue and valley oak

seedlings produced from directly seeded acorns. After 6 seasons, survival of seedlings free from competition is up to 5 times greater. However, in weed-free conditions, annual drought of 6 months or more contributes to mortality of seedlings developing in both classes of plant material. With protection from rodents, survival and growth of seedlings is significantly greater in nearly every circumstance. In the absence of weed competition, aboveground protection has doubled seedling survival and height in some blue oak plantings. Measured seedling losses from pocket gophers (*Thomomys* spp.) in 2 trials planted with and without underground protection have ranged from 50% (blue oak) to more than 90% (valley oak). In addition to other cultural practices, protection from rodent herbivory may be necessary to prevent failure of restocking programs. Risks associated with these programs suggest directly planted acorns are more practical than nursery stock.

Blue oak genetics field plot established by UC Berkeley forestry researcher Joe McBride, North Pasture, Spring 1992

3017. Adams, Theodore E., P. B. Sands, W. H. Weitkamp, and M. E. Stanley. 1997. **Oak seedling establishment by artificial regeneration on California rangelands.** Pp. 213-223 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: Blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*) seedling establishment on California rangelands is poor in many locations. Research on artificial regeneration is documenting that weed competition and small mammal and insect herbivory can contribute substantially to mortality where large herbivores are excluded. Success of natural oak recruitment and restocking and mitigation programs may be severely limited unless herbaceous plant control and protection against small mammals and insects are part of management activities.

3018. Adams, Theodore E., P. B. Sands, and W. B. McHenry. 1997. **Weed control improves survival of transplanted blue oak.** Calif. Agric. 51(5):26-30.
Abstract: Weed competition is recognized as a factor affecting survival of California blue oak seedlings in artificial plantings. Three alternative weed-control strategies were examined in a series of annual plantings at two locations using 2- to 3-month-old nursery stock. The effects of herbicides, porous plastic mulch mats, and impervious plastic mats were compared. No one strategy was superior, but all resulted in greater seedling survival than with no weed control, and generally also resulted in taller blue oaks. Use of herbicides was the least expensive weed control method. Much of the seedling mortality was attributed to depredation by rodents.

3019. Adams, Theodore E., P. B. Sands, and M. E. Stanley. 1997. **Oaks grown from nursery stock have better survival rate.** Calif. Agric. 51(1):26-29.
Abstract: Studies comparing the performance of blue and valley oak seedlings developing from directly planted acorns and 2- to 3-month-old nursery stock were conducted at several locations in California. Results suggest that transplanted blue oak nursery stock has a survival advantage over seedlings developing from directly planted acorns when the plant materials are grown together under the same conditions. However, the greater cost of nursery stock may make this plant material unattractive for restoration.

3020. Adams, Theodore E., P. B. Sands, and M. E. Stanley. 1997. **Research: Survival rate of oak nursery stock vs. acorns.** Am. Nurseryman 185(June 15, 1997):64-65.
Abstract: Summarizes same data reported in *California Agriculture* publication (# 3019, above), in brief. Transplanted blue oak nursery stock has a survival advantage over seedlings developing from directly planted acorns when the plant materials are grown together under the same conditions. However, the greater cost of nursery stock may make this plant material unattractive for restoration.

3021. Adams, T. E., Charles E. Vaughn, and P. B. Sands. 1999. **Geographic races may exist among perennial grasses.** Calif. Agric. 53(2):33-38.
Abstract: California's native perennial grasses have been largely replaced by alien annuals. Interest in restoration of native grasslands is strong, but genetic differences among the available collections of some grasses may affect the survival of plantings and remnant native stands. We planted nursery-propagated seedlings of 4 native California bunch grasses and one introduced bunch grass (for comparison) at two locations: Hedgerow Farms in Yolo County, and the Hopland R & E Center. In collections of the 4 native grasses examined, blue wildrye (*Elymus glaucus*), California melic (*Melica californica*), nodding needlegrass (*Nassella cernua*), and purple needlegrass (*N. pulchra*), differences in phenology, growth form and forage quality suggest the existence of geographic races. We recommend that accessions selected for mitigation, restoration, and range seeding should be chosen carefully to avoid contamination of relict gene pools. Phenological differences suggest that matching reproductive cycles to local climates may be necessary to insure the persistence of seedings.

3022. Bartolome, James W. 1976. **Germination and establishment of plants in California annual grassland.** Ph.D. Dissertation, Univ. Calif. Berkeley. 187 pp.
Abstract: The dynamics of annual plant populations and the effects of varying quantities of natural mulch on those populations was studied in an area of annual grassland at the Hopland Field Station of the University of California. Germination and establishment emerged as important population processes. Plant density differed in the two years of the study with maxima of 13.25/inch^2 in 1973-1974 and 20.76/ inch^2 in 1974-1975. Peak standing crop did not differ between years. Seed available in soil and litter prior to the start of the growing season declined between the first and second years. Observed patterns of fall establishment differed between years and among important species. Maximum overall plant density was reached in early winter after a steady and rapid increase through the fall. Plants declined by about 15 percent from winter through the spring with much sample variability. Most mortality occurred during the time of switch-over from dormant seed to seedling in the fall. Of the 40 seeds/ inch^2 present before the start of the season in the fall of

1974, only about half became established seedlings. Major grass species established differently. *Festuca* spp. and *Bromus mollis* germinated rapidly within the first few weeks of the fall growing season with a corresponding rapid loss of soil seed reserves, reaching peak densities in late fall. *Festuca* spp. and *Bromus mollis* seed produced and available at the start of the season in the fall was far in excess of observed seedling density. *Aira caryophyllea* and *Briza minor* germinated more slowly, not appearing until 1-2 weeks after the other fall species. *Briza minor* continued to germinate through the winter and spring from a large dormant soil seed reservoir. *Aira caryophyllea* seed was also present throughout the year, yet *Aira* seedlings reached peak density in mid-winter. *Aira* numbers declined through the spring. *Taeniatherum asperum* germinated in all seasons except summer, but unlike other grass species, soil seed supply at the start of the season was about equal to maximum seedling density, 0.90/ inch^2. Forbs and legumes exhibited a variety of species-specific patterns. *Erodium* spp. germinated within the first week of significant fall rainfall, with most of the stored soil seed used in that germination. Peak *Erodium* density, averaging about 0.8/inch^2 and reflecting a high probability of establishment for each seed, was reached within two weeks with little change in plant density thereafter. *Hypochoeris glabra* and legumes slowly increased through the fall in a manner similar to *Aira caryophyllea*, reaching a winter maximum. Estimates of *Hypochoeris* seeds produced and available as germinable soil seed were not adequate to account for observed seedling density. Mulch treatment at the end of summer left 0, 250, 500, 750, and 1000 lbs/acre. Effects may be summarized as follows: *Aira caryophyllea* and annual forbs including *Orthocarpus* spp., *Linanthus cilliatus*, and *Micropus californicus* were most abundant with all mulch removed. *Bromus mollis* was twice as abundant, 2.75 versus 1.25 plants/ inch^2, with 500 lbs/acre as at either higher or lower mulch treatments. Grass density increased with increasing mulch, especially *Taeniatherum asperum* at 1000 lbs/acre. *Erodium* spp., *Hypochoeris glabra*, and legumes showed little effect due to mulch treatment level. Maximum standing crop was unaffected by mulch the first year but increased linearly with mulch the second year. Descriptions of population patterns contribute to basic understanding of annual vegetation. Most of the loss of individuals from the population takes place during germination and establishment. Patterns established in the first weeks of the fall carry through the growing season little changed. For most plant groups studied available seed did not limit subsequent plant density, yet differences between seed produced in spring and available to germinate in fall were substantial. Many of the results of vegetation study are expressed as cover or biomass. Cover and biomass need to be linked to density for integration of management of productivity with population and genetic process.

3023. Bartolome, James W. 1979. **Germination and seedling establishment in California annual grassland.** J. Ecology 67:273-281.
***Abstract*:** Data for plant density, germinable seed in the soil, and seed production in annual grassland were obtained at Hopland Field Station in 1973 and 1974. The study combined indirect estimates of numbers of seed in the soil, germination in soil samples containing natural seed, and estimation of plant density. Autumn patterns of establishment differed significantly between the two study years. Plant density increased through the autumn, reaching peaks of 261.8 and 345.3 plants per dm^2 in the seventh week after germination began, in 1973 and 1974, respectively. The numbers of germinable seed in the top 6.4 cm of soil prior to the start of the growing season were 670.5 per dm^2 in 1973 and 610.2 per dm^2 in 1974, and thus showed little differences between years. Comparison of depletion of the seed-bank in the soil and increase of plant density showed that seeds germinating in the first week of the growing season produced fewer established seedlings than seeds germinating in the second or third weeks. The few seeds remaining in the fifth and sixth weeks had a high probability for successful establishment. Six species-groups exhibiting contrasting strategies for germination and establishment are discussed in detail.

3024. Bartolome, James W., and Barbara Gemmill. 1981. **The ecological status of *Stipa pulchra* (Poaceae) in California.** Madrono 28(3):172-184.
Abstract: We present information clarifying the past and present role of the native perennial grass *Stipa pulchra* in the California grassland. *S. pulchra* occupies a diverse array of habitats in northern and central California, as shown from information collected on more than 1500 plots by the State Cooperative Soil-Vegetation Survey. *S. pulchra* did not increase in density over a twenty-year period in ungrazed areas on the Hopland Field Station in northern California and was replaced by other perennial grasses and annuals on some plots. *S. pulchra* germinated more slowly than associated annual plants and *S. pulchra* seedlings apparently did not survive the period of rapid spring growth in annual grassland. In pot trials fewer *S. pulchra* germinated and plants grew poorly when grown in high densities of *Bromus mollis* and *Festuca megalura*. High densities of *B. mollis* limited *S. pulchra* growth more dramatically than high densities of *F. megalura*. We suggest that *S. pulchra* is the most common California native grass not because the species dominated the original California grass land, but because it is favored by disturbance common now. Disturbances that reduce associated annuals are important for colonization by *S. pulchra*.

3025. Bartolome, James W. 1986. **Herbaceous productivity in oak woodland.** Trans. West. Sect. Wildl. Soc. 22:112-116.
Abstract: Measurement of seasonal productivity over 3 years at the Hopland Field Station revealed significant differences in production and composition for the oak understory and adjacent open grassland. Productivity under the canopy was lower; about two-thirds of open grassland peak standing crop in spring, and about one-half of open grassland standing crop in winter. The understory and open grassland differed significantly in species composition, but differences in forage quality were not important until late in the spring. Although species composition differed substantially between years, composition differences due to canopy effect remained consistent over the 3 years of the study.

3026. Bartolome, James W., P. C. Muick, and M. P. McClaran. 1987. **Natural regeneration of California hardwoods.** Pp. 26-31 *in:* Proc. Symp., Multiple-Use Management of California's Hardwood Resources (T. R. Plumb and N. H. Pillsbury, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest For. & Range Expt. Sta., Gen. Tech. Rep. PSW-100.
Abstract: Concerns over insufficient regeneration to perpetuate hardwood species, largely based on inference from oak size distributions, have been expressed for over 75 years. During this period little progress has been made towards identifying factors which will prevent future regeneration, although favorite culprits enjoy repeated mention in the literature. Lack of information about past distribution and structure of hardwood stands limits interpretation of regeneration. Current stand structure may reflect excessive recruitment in the last century. Recent surveys have shown that patterns of past regeneration were highly species and site-specific, and probably not related to any single factor or repeated combination of factors. Regardless of the specific causes, current establishment appears insufficient to maintain current stand structures for some sites, although all major species are reproducing. Live oak species will increasingly dominate the state's woodlands under current land use if patterns persist.

3027. Bartolome, James W., and Mitchel P. McClaran. 1988. **Effect of fire and grazing on blue oak regeneration.** Final Report to Calif. Dept. of Forestry, Contract 8CA52961, Univ. Calif.

Berkeley. Pp. 1-17 + figs.
Abstract: Blue oaks are not regenerating well in California. The roles of fire and grazing in recruitment are not well understood, but historic fires closely associate with episodes of past blue oak regeneration in the foothill woodland. We burned three sites and for two years followed the progress of blue oak recruitment with and without browsing. Fires removed tops of 40 to 70 cm tall shrubby oaks, but they rapidly recovered. Without browsing, resprouts took only two years to reach preburn height. However, the observed growth rates would not elevate meristems above the browse line for at least five more years. Our results support the hypothesis that the close association of fire with blue oak recruitment is created by removal of stems which establishes a group of even-aged stem classes. We found no evidence that fire stimulates sprouting sufficiently to promote recruitment. On the studied sites, recruitment of resprouting shrubby individuals into the canopy would require 5-10 consecutive years of protection from browsing or many decades without protection. The combination of factors which allow for establishment of new plants from acorns remain undetermined. Fire and grazing had no lasting effect on 1- to 2-year-old seedlings of blue oak. They readily resprouted. However, the seedlings also showed no signs of growing into recruits. Seedling vigor declined with number of previous resprouts. Seedling age cannot be accurately determined from number of sprouts, since plants less than a year old already showed multiple resprouts. Although it does not directly benefit recruitment, fire is compatible with regeneration of blue oak and repeated fires would not have prevented or reduced historical recruitment of new plants.

3028. Bartolome, James W. 1989. **Local temporal and spatial structure.** Pp. 73-80 *in:* F. Huenneke and H. L. Mooney (eds.), Grassland Structure and Function: California Annual Grassland. Kluwer Academic Publ., Dordrecht, The Netherlands.
Abstract: This review focuses on ways spatial and temporal scale influences how researchers explain ecological processes in annual grassland. California's grassland ecologists have produced a remarkable body of information about the structure of these communities. Their success is due to recognition of temporal and spatial variation. Obviously, structural evaluation has allowed productive conjecture about important functional properties. Generally, this work has dealt more effectively with temporal than spatial pattern. I propose that this work was effective because early workers in the grassland developed clearly defined temporal scales. I also propose that the poorer record for work with spatial variation derived from the lack of a well-defined spatial scale. Although all ecologists have their preferred and perhaps explicitly defined spatial scales, the interrelationships between temporal scale, spatial scale, and identification of function are not usually carefully stated.

3029. Bedell, Thomas E., and Harold F. Heady. 1959. **Rate of twig elongation of chamise (*Adenostoma fasciculatum*).** J. Range Manage. 12(3):116-121.
Abstract: The rate of twig elongation and pattern of growth in the 1956 growing season were determined on three growth forms of chamise (*Adenostoma fasciculatum*). These were mature plants, hedged plants, and root crown sprouts. Crown sprouts grew faster and over a longer period than new twigs on either hedged or ungrazed mature plants. Top twigs on hedged plants were generally longer than side twigs. The higher the position of new twigs on mature plants the longer they became. The lengths of the growth periods were different with each growth form. Initiation of twig elongation occurred on approximately March 24 for the mature and hedged plants and slightly late for the crown sprouts. Elongation ceased by June 23 on mature plants, July 24 on hedged plants, and not until late autumn with the crown sprouts. Patterns of twig branching between growth forms were not markedly different except for the magnitude of branching. With the hedged and mature plants the majority of the twigs did not branch. Amount of vigor was assumed to be a factor in the amount of twig branching. Three growth responses occurred following removal of the terminal bud of twigs of mature plants: reproductive axillary growth, vegetative axillary growth, and enlargement of leaves. Some twigs showed no response. The greatest amount of vegetative lateral branching occurred in the spring period of good growing conditions and rapid plant activity. The greatest growth response over the entire growing season was leaf enlargement. This would indicate that additional plant material would be produced if twigs were grazed during the growing season.

3030. Brandl, Maria T., and Steven E. Lindow. 1998. **Contribution of indole-3-acetic acid production to the epiphytic fitness of *Erwinia herbicola*.** Appl. Environ. Microbiol. 64:3256-3263.
Abstract: *Erwinia herbicola* 299R produces large quantities of indole-3-acetic acid (IAA), a plant growth regulator, in culture media supplemented with $_{L}$-tryptophan. We hypothesized that the secretion of IAA may modify the microhabitat of epiphytic bacteria by increasing nutrient leakage from plant cells; enhanced nutrient availability may better enable IAA-producing bacteria to colonize the phyllosphere and may contribute to their epiphytic fitness. To assess the contribution of IAA production to epiphytic fitness, the population dynamics of the wild-type strain and an IAA-deficient mutant of this strain on leaves were studied. Strain 299XYLE, an isogenic IAA-deficient mutant of strain 299R, was constructed by insertional interruption of the indolepyruvate decarboxylase gene of strain 299R with the XYLE gene, which encodes a 2,3-catechol dioxygenase from *Pseudomonas putida* mt-2. The XYLE gene provided a useful marker for monitoring populations of the IAA-deficient mutant strain in mixed populations with the parental strain in ecological studies. A root bioassay for IAA, in which strain 299XYLE inhibited significantly less root elongation than strain 299R, provided evidence that *E. herbicola* produces IAA on plant surfaces in amounts sufficient to affect the physiology of its host and that IAA production in strain 299R is not solely an *in vitro* phenomenon. The epiphytic fitness of strains 299R and 299XYLE was evaluated in greenhouse and field studies by analysis of changes in the ratio of the population sizes of these two strains after inoculation as mixtures onto plants. Populations of the parental strain increased to approximately twice those of the IAA-deficient mutant strain after coinoculation in a proportion of 1:1 onto bean plants in the greenhouse and onto pear flowers in field studies. In all experiments, the ratio of the population sizes of strain 299R and 299XYLE increased during periods of active growth on plant tissue but not when population sizes were not increasing with time.

3031. Brooks, Colin N., Emily Heaton, David Newburn, and Adina Merenlender. 1998. **Modeling vineyard expansion in California's north coast and its consequences for the surrounding oak woodland landscape.** *In:* Nineteenth Annual ESRI User Conference Proceedings, San Diego, CA. 21 pp.
Abstract: Vineyards are expanding rapidly in California's north coast due to a booming wine market. In Sonoma County, much of this expansion is occurring on hillsides that harbor California's remaining oak woodlands. The pattern of vineyard development is influenced by physiographic, environmental, and land-use variables. Two statistical methods are used to examine which physical attributes are significantly related to vineyard development: 1) Ratios were calculated that are proportional to the probability of a particular site being planted in vineyard given that the entire landscape is developable. 2) Logistical regression was used to determine the relationship between physical variables and the probability of vineyard development. The ratio model was easier to calculate, while the logistic regression model allowed for the weighting of variables and found the most significant combination of variables.

Maps of suitable areas for future vineyard development were created using both techniques. These possible patterns of vineyard expansion can then be used to explore land-use planning and ecological effects. For example, we identified areas where vineyard development could lead to oak woodland fragmentation.

(Above) Watershed II at Hopland in 1969, about 10 years after woody vegetation was cleared and burned; (Below) Watershed II in 2001, demonstrating natural revegetation by live oaks and other riparian plants

3032. Brooks, Colin N., and Adina M. Merenlender. 1998. **Return of natural hardwood regeneration in a cleared watershed.** Oaks 'n' Folks 13(2).
Abstract: Through use of aerial photographs and GIS, we studied regeneration of woody plants in a watershed at the Hopland R & E Center that was cleared by use of herbicides and controlled burning in the early 1960s. It was determined that hardwood, riparian, and chaparral regeneration all occurred between 1968 and 1996, but most of the watershed remained in grassland. Most evergreen oak regeneration occurred on moist, north-facing slopes, even while subjected to livestock and deer browsing. Without active restoration efforts, drier southerly slopes will likely remain sparsely vegetated.

3033. Brooks, Colin N., and Adina M. Merenlender. 2001. **Determining the pattern of oak woodland regeneration for a cleared watershed in northern California: a necessary first step for restoration.** Restoration Ecol. 9(1):1-12.
Abstract: Historically, oak woodlands of northern California have been subject to intensive tree and brush removal efforts to improve land for livestock grazing. As a result of this tree removal, these watersheds are susceptible to soil erosion and stream degradation. Therefore, planting woody vegetation is often required to restore watershed function. Prior to such actions, a thorough understanding of natural vegetation regeneration patterns is essential. The physical and biological attributes of natural vegetation regeneration in a cleared watershed were characterized using remote sensing, a Geographic Information System, and field surveys. A 79-ha watershed at the University of California's Hopland Research and Extension Center was examined because the clearing of vegetation was part of a well-documented experiment in the early 1960s, providing essential baseline data. The results of this study reveal that significantly more oak regeneration, consisting mostly of evergreen oaks, occurred on moister and steeper northerly slopes. Deciduous oaks, located primarily on drier and less steep southerly slopes, have not regenerated. Hardwood regeneration was associated with Josephine, Los Gatos, and Maymen soils. The distribution of hardwood regeneration is clustered, suggesting that the presence of other trees may promote regeneration. These results also suggest that without active restoration efforts such as tree planting and seedling protection, southerly slopes will most likely remain barren and erosion will continue, while northerly slopes and riparian areas will recover under the current land management practices. Despite some woody plant regeneration, the once densely forested watershed is now predominantly grassland, emphasizing the need to minimize clearing of California oak woodlands.

3034. Buttery, Ron G., Dale R. Black, Dante G. Guadagni, Louisa C. Ling, Guy E. Connolly, and Roy Teranishi. 1974. **California bay oil. I. Constituents, odor properties.** Agric. and Food Chem. 22(5):773-777.
Abstract: The steam volatile oil of the leaves of California "bay" tree (*Umbellularia californica*) was analyzed by capillary and packed column gas chromatography separation with characterization by mass and infrared spectrometry. The characterization of the major components umbellulone (39%), 1,8-cineole (19%), α-terpineol (7.6%), terpinen-4-ol (6.2%), sabinene (6%), α-pinene (4.7%), and 3,4-dimethoxyallylbenzene (5.4%) was confirmed and 26 additional compounds also characterized. Odor threshold studies indicated that 1,8-cineole was by far the major contributor to the odor of dilute water solutions of the oil. Comparison of the composition and odor properties was made with other well known "bay" oils from the leaves of Mediterranean bay (*Laurus nobilis*) and West Indian bay (*Pimenta racemosa*).

3035. Byron, Janet. 2001. **Genetic variation data could help blue oak reseeding efforts.** Calif. Agric. 55(6):11.
Abstract: This brief article reports on ongoing studies by UC Berkeley researcher Joe McBride on blue oaks at Hopland and elsewhere. Loss of genetic diversity as a result of conversion of blue oak woodlands to savannah and grassland has stimulated research to define the amount of genetic diversity in this species by means of planting "common garden" plots at research locations. Planted in 1992, blue oak seedlings originated from seed sources at 26 locations from throughout California. Eight years into the experiment, McBride has found some trends in blue oak genetic variation, expressed as differences in shoot growth, phenology, and mineral accumulation. Longer dormancy in oaks from higher elevation locations indicates that dormancy may be temperature-related. This work could eventually serve as a basis for developing seed-acquisition rules and gene conservation strategies.

3036. Caprio, Joseph M. 1991. **Departure of honeysuckle and lilac begin bloom dates from normal in 1991 throughout the western region of the United States. A report to cooperators of the phenological survey in the western region of the United States.**, Montana Agricultural Experiment Station, Bozeman, MT.

10 pp.
Abstract: Observations regarding plant phenology made throughout the western U.S. have contributed to our understanding of the pattern of plant development throughout the western region. Modeling of requirements to trigger flowering in lilac and honeysuckle continues, based on data collected from observers throughout the region, including Hopland. At any given location, the relative time of honeysuckle and lilac will differ from year to year. The average difference in bloom dates of these two species, however, shows a distinct pattern over the western region. An understanding of the causes underlying the relative timing of the flowering sequence of deciduous perennial plants could help anticipate pollination problems caused by future climatic warming.

3037. Costello, Laurence R., Robert H. Schmidt, and Gregory A. Giusti. 1991. **Evaluating tree protection devices: effects on growth and survival – first-year results.** Pp. 31-35 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage. (R. B. Standiford, tech. coord.), Davis, CA. USDA For. Serv., Gen. Tech. Rep. PSW-126.
Abstract: This paper reports on the effects of three protection devices (treeshelters, plastic mesh screens, and wire screens) on the growth and survival of seedlings of blue oak (*Quercus douglasii*), valley oak (*Q. lobata*), interior live oak (*Q. wislizenii*), and Douglas fir (*Pseudotsuga menziesii*) under irrigated and non-irrigated conditions. Survival of all species was generally good when irrigated, regardless of protection device. Survival was lower for all species when not irrigated. Only 2 of 50 Douglas fir seedlings survived without irrigation. Results of the protection device treatments on growth must be considered preliminary as only 5 months had elapsed. However, protection devices did enhance top growth during this time, particularly the tree shelters on irrigated oak seedlings. Protection devices appeared to promote growth on non-irrigated oaks as well. In this study, height and diameter growth will be monitored for another 2 years.


Robert M. Timm

Plastic cylindrical 'Treeshelter' tubes were found to be effective in enhancing growth of oak seedlings, 1994

3038. Costello, Laurence R., Amy Peters, and Gregory A. Giusti. 1996. **An evaluation of treeshelter effects on plant survival and growth in a Mediterranean climate.** J. Arboriculture 22(1):1-9.
Abstract: A 4-year study was conducted to evaluate the effect of treeshelters on the growth and survival of 3 oak species (blue oak, valley oak, and interior live oak) and Douglas fir growing in a Mediterranean climate. Trees were planted in irrigated and nonirrigated plots, enclosed in treeshelters or tree guards, and measured annually for height and diameter of growth. In nonirrigated plots, both treeshelters and tree guards improved oak survival, but generally did not produce significant height or diameter growth increases over unprotected controls. In irrigated plots, plant growth was substantially greater than that in nonirrigated plots. Irrigated trees with protection (shelters or guards) showed substantially greater survival levels than unprotected trees. Height growth was greatest in treeshelters and diameter growth was roughly equivalent for all irrigated treatments. Irrigated trees continued to grow when irrigation was discontinued after three years, and tree shelter trees exhibited little or no lean when shelters were removed. Trees without irrigation in Mediterranean climates should not be expected to exhibit growth enhancement effects from treeshelters equivalent to those in temperate climates.

3039. Crampton, Beecher. 1956. **Report on the floral composition under chemically treated oak species at the Hopland Field Station (South Pasture).** Univ. Calif. Davis. 1 p.
Abstract: Vegetation development under both live oak and blue oak trees, which were killed by use of herbicides, was monitored. Under live oaks, herbaceous cover was reported to be 50-80%, a 25-30% increase over the previous year. The dominant species were ripgut (*Bromus rigidus*) 40-50%, Spanish brome (*Bromus madritensis*) 10% or less, and red brome (*Bromus rubens*) 5% to less. A notable increase of the shade-loving annual bur chervil *Anthriscus scandicina*, an undesirable forage plant, to 5% of vegetation cover, was noted. Various other grasses and forbs were present in stable, minor amounts. Under blue oaks, ripgut and mouse barley (*Hordeum leporinum*) were noted to cover about 55% of the area under treated oaks, with some fluctuation but not significantly different from previous years, and not greatly different than vegetation under untreated oaks. Since the previous year, some decrease in hedge parsley (*Torilis nodosa*) and short-pod mustard (*Brassica incana*), both from 15% each in 1955 to only 5% or less, was seen. Much branch and long debris was noted under the killed trees. While it is logical that removal of evergreen oaks increases the amount of area for herbaceous expansion, at present aggressive annual pioneer grasses are dominant and are of different species and genera than those present on open, exposed slopes. The forage value of the grasses from both habitats is comparable. Blue oak treatments have not appreciably altered the nature of the forage beneath their canopies.

3040. Dell, Ken, Glenn McGourty, Doug Gubler, and Kevin Klein. 1995. **Pear scab fungicide and timing trials 1 and 2, Hopland Research Station, Mendocino County.** Pp. 81-89 *in:* Plant Pathology Cooperative Extension Projects, Dept. of Plant Pathology, UC Davis.
Abstract*:* Fungicides were tested in two young pear orchards, Bartlett and Red Sensation, for efficacy against pear scab, *Venturia pirina*. Fungicides treatments included Procure 50WS, Procure + Dithane 75DF, Thiram, Ziram 76W, and Hytech Oil 2%, in addition to a control. Applications of different materials were timed either on a weather driven alarm system or on a calendar basis. The alarm system was an Adcon weather station and disease forecast model of apple scab, *Venturia inequalis*. This disease is considered similar enough to pear scab to work as a predictor of treatments needed. Calendar based treatment materials were applied at weekly intervals from green cluster through fruit set and thereafter previous to any expected rain through the end of April. The trial was conducted during the highest period of susceptibility, from initial budbreak (green cluster) through petal fall, to the ½" fruit stage. Treatments on the alarm system basis received 5 applications during this time, while treatments on the calendar system received 8 applications. Fruit was rated for scab on May 20 and again for scab, fruit weight, and total yield just prior to harvest, on August 2. No treatment provided adequate disease control. Incidence of lesions for most treatments

was high at the early rating and increased only slightly be the pre-harvest rating, the exception being the Procure + Dithane treatment. This indicates that control was lost during bloom to fruit set. The most successful treatment was Procure + Dithane applied on the alarm timing schedule. Even with the poor overall control, the ratings indicated that the alarm timing system can be an efficient and effective method of timing applications.

3041. DiTomaso, Joseph M., Kerry L. Heise, Guy B. Kyser, Adina M. Merenlender, and Robert J. Keiffer. 2001. **Carefully timed burning can control barb goatgrass.** Calif. Agric. 55(6):47-53.
Abstract: Barb goatgrass (*Aegilops triuncialis*) is a noxious annual grass that is rapidly invading California's grassland ecosystems. No effective control strategies for managing barb goatgrass have been available that do not simultaneously injure other more desirable grass and broadleaf species. In our study at the Hopland Research and Extension Center, we conducted prescribed burning in late spring or early summer before barb goatgrass seeds had reached maturation. One year of prescribed burning was not sufficient to control reestablishment the following year. However, 2 years of complete burning gave effective control of barb goatgrass while increasing native perennial grass cover and native species richness, particularly legumes. The success of the goatgrass control was directly proportional to the completeness of the second-year burn. In California, suppression of periodic fire has dramatically changed the composition of rangelands. For noxious annual such as barb goatgrass, medusahead, ripgut brome, and yellow starthistle, fire suppression can lead to their dominance in grasslands. Reintroduction of timed burns to rangelands can remove litter, recycle nutrients, stimulate tillering in perennial grasses, and reduce noxious annual grass or broadleaf weed seedbanks. In addition, fire has been shown to be beneficial to the maintenance of perennial bunchgrass populations and other native broadleaf species, particularly native legumes such as clovers, Gambel's locoweed, and Wrangel's trefoil.

3042. Erickson, Mandy. 2001. **European grapes tested in North Coast vineyards.** Calif. Agric. 55(6):10.
Abstract: This progress report summarizes work being done by Glenn McGourty at Hopland to evaluate the performance of 19 European cultivars of winegrapes that may be particularly well-suited to certain California climatic zones. Begun in 1994 on a 2-acre plot in HREC's Niderost pasture, the test vineyard produced its first crop of winegrapes in fall 2000. The varieties Montepulciano, Fiano, and Corvina appear to show particular promise in early results.

Guy E. Connolly

HFS crew harvesting grapes from research vineyard, Niderost Pasture, October 1973

3043. Eviner, Valerie T. 2000. **Case studies: vineyard vegetation. Ecological principles of vineyard vegetation management on California's north coast**. Agroecology Research Group. Web page www.agroecology.org/cases/vineyardcover.htm, accessed Feb. 24, 2000.
Abstract: Information on this web site outlines and summarizes interrelationships among types of native and introduced vegetation in vineyards in Mendocino County. Interactions between grapevines and other vegetation is discussed. Benefits and disadvantages of use of cover crops in vineyards are listed, and factors to consider when choosing cover crops are outlined. Characteristics and attributes of typical legumes, grasses, and forbs are presented in tabular format.

3044. Eviner, Valerie T., F. Stuart Chapin III, and Charles E. Vaughn. 2000. **Nutrient manipulations in terrestrial ecosystems.** Pp. 291-307 *in:* O. E. Sala, R. B. Jackson, H. A. Mooney, and R. W. Howarth (eds.), Methods in Ecosystem Science. Impressions Book and Journal Services, Inc., Madison, WI.
Abstract: Nutrient addition experiments can be used to address a variety of questions, including the role of nutrients in mediating ecosystem processes, nutrient effects on plant and microbial community dynamics, the limitations on plant growth and ecosystem production, and the response of ecosystems to increased atmospheric deposition of nutrients. When designing a nutrient addition experiment, it is critical to minimize the impact of the fertilizer additions on soil pH, salt toxicity, and the supply of other potentially limiting nutrients that are not being tested (e.g., S, Ca). It is also important to understand whether a lack of response to fertilization is due to the absence of limitation for that nutrient, or the failure of the nutrient additions to become available to plants. This is especially important when comparing responses of plant growth to nutrient additions across sites, where factors controlling fertilizer availability could differ substantially. Isotopes are an invaluable tool for attaining a mechanistic understanding of the fate and dynamics of nutrient additions. They can be used to test how much of the fertilizer becomes available to plants, elucidate mechanisms of nutrient retention and loss, detect changes in soil nutrient dynamics, and trace competitive uptake between different plant species and microbial groups. The incorporation of isotope methods into nutrient addition experiments should solidify our understanding of the controls of nutrients over all aspects of the ecosystem.

3045. Eviner, Valerie T. 2001. **Linking plant community composition and ecosystem dynamics: interactions of plant traits determine the ecosystem effects of plant species and plant species mixtures.** Ph.D. Dissertation, Univ. Calif. Berkeley. 404 pp.
Abstract: I examined the mechanisms by which plant species and plant species mixtures influence N dynamics, soil phosphorus, and decomposition in a California annual grassland. I established plots of eight grassland species in monoculture, and in two-, three-, and five-species mixtures. Plant species influenced ecosystem processes through an interaction of different mechanisms, including litter quality and quantity, aboveground live biomass, labile carbon (C) inputs (exudation and tissue turnover), and influences on soil microclimate (Chapter 1). Species affected ecosystem processes through unique combinations of these mechanisms, and the relative importance of these mechanisms changed over time. Litter quality was the dominant mechanism by which plant species influenced early stages of decomposition, but labile C inputs became more important in the later stages of decomposition. Plant species effects on nitrogen (N) cycling were in part dependent on both litter quality and labile C inputs, but plant effects on soil temperature and moisture played a critical role at the time of the growing season when these factors most limited plant growth and microbial activity. Plant composition had only small effects on soil phosphate and microbial phosphorus (P), which were more strongly influenced by other factors such as slope position. In order to understand the roles plant species play in ecosystems, it is vital to consider how they influence the activity and distribution of other organisms that play large roles in ecosystems.

Plant species influenced the timing, type and extent of gopher activity, and in turn, this plant-gopher interaction greatly altered patterns of nitrogen cycling (Chapter 2). Plant species were also associated with distinct functional profiles of the bacterial community (Chapter 3); these profiles were closely related to plant labile C inputs. While these interactions between the plant community and bacterial community function, independent of plant composition, also correlated with ecosystem processes. Bacterial C utilization profiles in plant mixtures were not an additive function of the component monocultures, and this may, in part, account for the non-additive effects of plant mixtures on ecosystems. The non-additive effects of plant mixtures were also related to combinations of plant substrates impacting the activity of the microbial community. For example, legumes enhanced decomposition of recalcitrant litter. Another mechanism that accounted for non-additive effects of plant mixtures on ecosystem processes was changes in plant traits when grown in mixture. Shifts in litter quality, labile C inputs, aboveground biomass, and effects on soil temperature all were associated with non-additive effects of plant mixtures on N cycling. Overall, plant traits can be used to understand many effects of plant communities on ecosystems by providing mechanistic links between ecosystem processes and the interactions between plant traits, plant species, and plants with other organisms.

3046. Eviner, Valerie T., and F. Stuart Chapin III. 2001. **Animals and fungi can affect goatgrass establishment.** Calif. Agric. 55(6):53.
Abstract: The fungus *Ulocladium atrum* has been noted to enhance establishment of barb goatgrass (*Aegilops triuncialis*), as it helps break down the tough, woody seedhead, thus speeding germination. Conversely, small rodents (voles and/or mice) on rangeland were noted in two field experiments to prey heavily on planted barb goatgrass seed following planting. Pocket gophers (*Thomomys bottae*) selectively built mounds in goatgrass plots, completely burying the goatgrass and killing most of the seedlings. While more research is needed, it appears that the fungus as well as small rodents can play a significant role in establishment of this invasive weed.

3047. Eviner, Valerie T., and F. Stuart Chapin III. 2001. **Plant species provide vital ecosystem functions for sustainable agriculture, rangeland management and restoration.** Calif. Agric. 55(6):54-59.
Abstract: Plants respond to and change their environments, actively altering factors such as soil stability, nutrient and water availability, and the distribution of pests and beneficial organisms. By identifying the functions associated with different species and the effects they have on their ecosystems, managers can use plants as tools in agriculture, range management and restoration, since they will be able to choose plants more effectively and anticipate unintended consequences of vegetation changes. Because cover crops have been used in agricultural settings for years, much is known about their functioning and response to environmental conditions and management practices. Much less is known about plants in natural systems, yet this information can be critical to range management and restoration. We compare what is known about grassland plant functions in California by reviewing the extensive research that has been undertaken at the Hopland Research and Extension Center. In doing so, we discuss such topics as nitrogen availability, undesirable plant invasions, soil structure, the effects of small mammals on plant communities, and vegetation management.

3048. Ewing, Anne L., and John W. Menke. 1983. **Reproductive potential of *Bromus mollis* and *Avena barbata* under drought conditions.** Madrono 30(3):159-167.
Abstract: In California annual grasslands, flowering and seed set occur during spring when soil water conditions change rapidly due to increased plant growth, high evapotranspiration, and infrequent rainfall. This study simulated short drought periods and an early onset of summer drought to determine possible drought effects on seed production and population carry-over of *Bromus molli*s and *Avena barbata*. Drought treatments diminished seed production, but some germinable seeds were produced under severe conditions. Drought effects carried over to the next generation because stressed plants produced smaller seeds that produced smaller seedlings.

3049. Freney, J. R., K. Spencer, and M. B. Jones. 1977. **On the constancy of the ratio of nitrogen to sulphur in the protein of subterranean clover tops.** Commun. Soil Sci. Plant Anal. 8(3):241-249.
***Abstract*:** The use of plant analysis for the diagnosis of the sulfur status of plants is gaining acceptance. Total S and SO_4 concentrations have been used for this purpose, but concentrations vary by plant part, age, and nutrient supply. This study investigated the use of N:S ratios as a means of evaluating plant sulfur status. While total N:total S ratios varied widely from 4 to 331 depending on plant part, age, N supply, and S supply, there was no discernable trend in protein N:protein S ratios attributable to any of these factors. The results also show that it is difficult to extract all of the non-protein N and non-protein S from plant tissue. This could explain the variation in protein N:protein S ratios found by some workers.

3050. Freney, J. R., K. Spencer, and M. B. Jones. 1978. **Determining the sulphur status of wheat.** Sulphur in Agric. 2.
Abstract: Unlike North America, there is little documented evidence of sulfur deficiencies in the wheat-growing areas of the Southern Hemisphere. In Australia, there is some evidence that sulfur in soil may be limiting to the yield of this crop. A number of procedures for assessing sulfur status in wheat were recently compared in a glasshouse experiment. The indices studied (total sulfur, sulfate sulfur, total nitrogen:total sulfur ratio, amide nitrogen and sulfate as a percentage of the total sulfur) have been suggested for the diagnosis of the sulfur status of a number of other plants. The ideal procedure for use in tissue testing would require simple sampling and handling of samples, straightforward analytical techniques, and yet provide critical values which are least susceptible to the factors known to influence plant composition. On the present evidence, the index having the fewest drawbacks is the proportion of sulfur present as sulfate. Finally, there are reservations concerning the application of these findings obtained in pot cultures to field conditions. The high rate of demand for sulfur under glasshouse conditions combined with a limited zone for root exploration leads to a more rapid exhaustion of the sulfur supply than in the field. The promising relationships that were obtained, and the magnitude of the changes induced, need confirmation in the field for the variety and the environmental conditions under which wheat is grown.

3051. Freney, J. R., K. Spencer, and M. B. Jones. 1978. **The diagnosis of sulphur deficiency in wheat.** Aust. J. Agric. Res. 29:727-738.
Abstract: In a glasshouse experiment with wheat (*Triticum aestivum*), changes in the concentrations of total sulfur, sulfate sulfur, amide nitrogen, and total nitrogen/total sulfur ratio with age, plant part, and nitrogen and sulfur supply, were studied. This was done so that more reliable methods can be devised for the assessment of the sulfur status of this species. Each of the indices studied was strongly related to the current and subsequent sulfur status of the wheat plant. Amide nitrogen provided the greatest relative change in values between sulfur-deficient and sulfur-adequate plants, and on that basis was the most sensitive index. However, each of these indices had shortcomings which could preclude its general acceptance as a useful indicator of sulfur status. The most promising index of sulfur status was shown to be the proportion of total sulfur held as sulfate. This criterion was unaffected by nitrogen supply or plant age. The data suggest that wheat plants containing more than one-tenth of their

sulfur as sulfate are adequately supplied with sulfur.

3052. Frost, William E., James W. Bartolome, and J. Michael Connor. 1997. **Understory-canopy relationships in oak woodlands and savannas.** Pp. 183-190 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: We summarize available information about the relationships between oak overstory and understory plants for major California rangeland types. Understory biomass, productivity, and plant species composition vary considerably because of geographic location, overstory species composition, and overstory density and distribution. Deciduous oak canopies in areas with less than 50 cm annual precipitation generally have either no effect or enhance understory productivity compared to adjacent grassland. Dense canopies in areas with more than 50 cm annual precipitation generally suppress understory productivity. Forage management implications are summarized for different woodland types around the state.

Tracy Borland

UC Berkeley graduate student Mike Fry examines black oak branches, 1976

3053. Fry, Michael E. 1983. **Acorn production and the value of oak forage to wildlife and livestock in California.** M.S. Thesis, Univ. Calif. Berkeley. 85 pp.
Abstract: Blue oak, California black oak, and interior live oak production of acorns and litter (leaves, twigs, lichens) were monitored for two years. During a good mast year, blue oak, interior live oak, and black oak respectively produced 2955, 1074, and 616 kg/ha of tree canopy; while during a poor year they respectively produced 88, 614 and 36 kg/ha of tree canopy. Nutrient-content analyses showed that oak leaves and twigs can supply the dietary requirements of ruminants for protein and phosphorus in spring and fall and that oak-associated lichens supply a rather steady year-long 9% crude protein source. Rumen-content analyses on 61 black-tailed deer showed that acorn quantities in the diet of 5% or more appear first in July, and quantities and frequency of occurrence increased through October and dropped sharply in November. Oak-associated foods accounted for more than 60% of the deer's diet in summer and more than 36% in fall on the Hopland Field Station. Thirty-two yearling ewe lambs were fed 0%, 10%, 20%, or 30% of their diet as acorns in a 41-day feeding trial simulating fall field conditions. Acorns were shown to be valuable dietary supplement since animals in the zero-level group lost 0.86 lb/week while animals in the 30% acorn supplement group gained an average of 0.32 lb/week. The high-carbohydrate and solid-fat composition of the acorn, as well as high tannin level, was suggested as the reason for the inverse relation between blood urea nitrogen and serum cholesterol responses over the range of acorn supplements fed.

3054. Giusti, Gregory A., Robert H. Schmidt, and Kenneth R. Churches. 1991. **Oak sustainability: a challenge through public education and outreach programs.** Pp. 246-249 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage. (R. B. Standiford, tech. coord.), Davis, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-126.
Abstract: Throughout California, public awareness on the role humans play in the decline of oak acreage is increasing. Public and private organizations, agencies, and individuals are instituting planting days, releasing articles on oaks to the media, and sponsoring lectures. Many of these activities are limited in scope and lack a strong educational component that promotes sustainability. Educational programs certainly need to address such issues as site selection and preparation, acorn selection and storage, nursery propagation, species identification, and audience identification. This paper discusses sustainability as it relates to stand restoration and landscape-wide ecosystems. Educational delivery methods are examined and potential audiences defined.

3055. Gordon, Doria R., and Kevin J. Rice. 1993. **Competitive effects of grassland annuals on soil water and blue oak (*Quercus douglasii*) seedlings.** Ecology 74(1):68-82.
Abstract: Four California annual grassland species were used to examine the hypothesis that different plant species have equivalent competitive effects. We investigated the effects of the annuals on soil water availability and the growth responses of blue oak (*Quercus douglasii*) to neighbor-induced water depletion. Neighborhoods of annuals were composed of species from the California annual grassland with differing phenology and morphology that were hypothesized to show non-equivalent competitive effects on both a per-individual- and a per-unit-tissue basis. Three introduced species of winter annuals were sown at each of three densities (10, 30, or 100 seeds/dm^2) around a single oak acorn. The grass *Bromus diandrus* and the forb *Erodium botrys* flower in early spring, while the grass *B. mollis* flowers slightly later. A native summer annual forb, *Hemizonia luzulaefolia*, was sown at only the intermediate density. Plants were grown outdoors in 15 cm diameter × 1 m deep tubes filled with soil from an oak woodland site. Identity and density of annual species had independent and interactive effects on the water resource level. Soil water potential was negatively density-dependent, remaining highest when oaks were grown without competitors. At the intermediate density soil water potentials decreased in the following order *B. mollis* (slowest), *B. diandrus*, *E. botrys*, and *H. luzulaefolia* (most rapid). This order followed the pattern of root length developed in the neighborhoods, which was species- and density-dependent. The relationship between sowing density and neighborhood dry mass also differed among the annual species. Correlations between root length and soil water potential were stronger for the forbs than for the grasses. A given root length of the summer annual, *H. luzulaefolia*, depleted soil water to a greater extent than did the same root length of any other species. Oak seedling growth, gas exchange rates, and survivorship were negatively related to the rate and extent of soil water depletion. Additionally, the relationship between annual root length and oak seedling height or root length differed by neighborhood species. Thus, neighborhood species were non-equivalent in competitive effect on both a per-individual and a per-unit-root-length basis. Phenologically different species may represent different functional groups of competitors.

3056. Gross, Rob. 1988. **Impacts of insect defoliation on oaks.** Oaks 'n' Folks 3(1):2-3.
Abstract: Oaks are host to a multitude of insects, including those that consume foliage. While unsightly, insect defoliation is usually not a

serious problem unless it is severe, repetitive, or coupled with other stress factors. Severe defoliation can reduce tree vigor, making the oak more susceptible to other stresses such as drought, fire, or other insects. Sometimes following defoliation, trees will produce a new crop of leaves. The best way to minimize detrimental effects of insect defoliation is to maintain healthy trees by providing an optimal growing environment.

3057. Gross, Rob, and Robert H. Schmidt. 1989. **Irrigating native California oaks.** Oak Information Project Publication No. 1, Dept. of Forest & Resource Management, Univ. Calif. Berkeley, Hopland, CA. 1 p.
Abstract: Irrigating native California oaks is both unnatural and problematic in most situations. Native oaks are well adapted to the dry summers in California. Warm season irrigation changes the root environment of native oak dramatically, which can lead to premature oak death. Both the oak root fungus *Armillaria mellea*, and another root fungus group commonly called the water molds, can if encouraged by warm-season irrigation weaken and kill the host oak tree. Appropriate landscaping near native oaks should utilize drought-tolerant plants, either native or exotic, that do not require summer irrigation.

3058. Gulmon, S. L. 1977. **A comparative study of the grassland of California and Chile.** Flora 166:261-278.
Abstract: Immigrant species from Eurasia have become established in areas of similar climate in California and Chile where they comprise annual grassland vegetations of considerable structural and floristic similarity. However, analysis of associations among species indicates that the similarities do not extend to finer levels of organization. Land use practices and short term climatic variability are believed to account for the differences. This study, conducted in conjunction with the International Biological Program, sampled and compared grasslands near Santiago, Chile and San Diego, California. To attempt to discriminate the effects of climate from those of geography and land use, additional grassland sampling was also conducted at sites in Hopland and Palo Alto, California. These two northern California sites were proved to be floristically similar and were lumped for analysis. It was concluded that the coast range annual grassland vegetation of California and Chile is remarkably congruent overall. Of the 87 species sampled in Santiago, a total of 58 occurred identically (29 species), as members of common genera (15 species), or as morphological analogs (14 species) in northern California. An additional 6 species from Chile, which were not found at Palo Alto or Hopland, were sampled in San Diego. Similarly, 65 of the 85 species in northern California had identical (29), closely related (20), or analogous (16) members in the Chilean sample. The primary similarity between samples from the two hemispheres, including nearly all of the identical species, was among those taxa that were introduced from Europe or the Mediterranean. In addition to the relationships between species and their analogs, the grasslands in Chile and California are assembled in a similar way, both dominated by introduced grasses and *Erodium* species. Although the floristic relationship between the grasslands was evident, the patterns of structure and diversity were quite different. Chile was structurally much more similar to northern California than to its climatic analog, San Diego. There was also greater diversity in Chile. The difference can be explained in part by subtle climatic differences between the two continents; in short, California is drier and somewhat warmer than Chile at equivalent latitudes. It is possible that soil microorganisms or disease-causing agents affect species relationships differently in California. However, the most probably explanation for increased diversity in Chile is heavier grazing intensity and lower soil fertility.

3059. Handley, Raymond, R. K. Schulz, H. Marschner, R. Overstreet, and William M. Longhurst. 1967. **Translocation of carrier-free ^{85}Sr applied to the foliage of woody plants.** Radiation Botany 7:91-95.
***Abstract*:** Carrier-free ^{85}Sr was applied to the foliage of three genera of woody forage plants (*Ceanothus*, *Adenostoma*, and *Quercus*) and subsequent translocation into untreated portions of the plants was measured. Experiments were conducted in the field and in the greenhouse. In all cases the bulk of the retained dose remained with the directly treated material. However, substantial concentrations of ^{85}Sr were found in the new growth arising on previously treated branches of *Ceanothus* and *Adenostoma*. The amounts translocated under field conditions under which plants were subject to periodic wetting and drying were greater than those translocated by plants in the greenhouse.


Robert M. Timm
The lichen *Ramalina reticulata* is common on oaks at Hopland

3060. Handley, Raymond, and Roy Overstreet. 1968. **Uptake of carrier-free ^{137}Cs by *Ramalina reticulata*.** Plant Physiol. 43(9):1401-1405.
Abstract: Concentrations of fallout radionuclides found in lichens are usually much higher than those in associated higher plants. This study examines the mechanisms of uptake of ^{137}Cesium in a lichen collected from Hopland. The uptake of carrier-free ^{137}Cs by *Ramalina reticulata* does not appear to be directly linked to metabolism. The results indicate the presence of a barrier to entry of ^{137}Cs. The barrier is stabilized by Ca ions. Removal of Ca by pretreatment of the tissue in monovalent salt solutions increases the uptake of ^{137}Cs. Uptake under anaerobiosis is also greater than normal, but in this case, Ca displaced from the barrier membrane is not lost from the tissue and normal permeability is rapidly reestablished when aerobic conditions are restored. Under anaerobiosis Ca^{2+} increases damage to the respiratory mechanism presumably by increasing retention of toxic products.

3061. Hart, Jonathan J. 1984. **Water relations of two California chaparral shrubs.** M.S. Thesis, Univ. Calif. Davis. 58 pp.
Abstract: Water use patterns of two California chaparral shrub species, chamise (*Adenostoma fasciculatum*) and Stanford manzanita (*Arctostaphylos stanfordiana*), were compared during summer drought. Observations of diurnal and seasonal courses of shoot water potential, leaf conductance, and transpiration revealed that chamise may be more conservative in water use than manzanita. An attempt to duplicate a previously observed anomalous diurnal shoot water potential pattern in chamise was not successful due to lack of sufficient water stress during the two drought seasons of this study. A hypothesis proposed to explain the anomalous pattern was reviewed.

3062. Heady, Harold F. 1956. **Evaluation and measurement of the California annual type.** J. Range Manage. 9(1):25-27.
Abstract: The California annual-grass type is extremely varied. It is found in a wide variety of environmental and geographical conditions over a broad range of soil types. Three patterns of vegetational changes must be considered in evaluating the annual type range. The first occurs through the growing season and may be illustrated by numbers of plants by species in a given area. If this composition is the primary consideration, then range evaluation should be near the end of the growing season when the full forage crop is present. The second source of change in species composition occurs from one year to the next. Composition is never the same in successive years and any system of range condition classification must be broad enough to include these variations. The third source of change results from the degree of grazing pressure on the range. This influence is exerted largely through the amount of plant residue present from the period of germination through winter. Leaving 700 to 1,000 pounds of residue per acre has resulted in beneficial changes in floral composition and production. Finally, plant succession does occur in the annual type and therefore changes in the floral composition can logically be used as a yardstick to aid in the designation of range condition. Evaluating certain plants contrary to this natural succession can lead to grazing use requirements incompatible with maximum production.

3063. Heady, Harold F. 1957. **The measurement and value of plant height in the study of herbaceous vegetation.** Ecology 38(2):313-320.
Abstract: Different concepts of plant height and difficulties of measurement are reasons for seldom publishing such data. A method of measuring height with the point-plot method is described. Advantages of this method include objectivity, ease in operation, and the addition of another measurement to those normally collected with the point system. Even though field application has not been attempted outside the California annual type, the method should be useful wherever the point system is applicable. There is a continuous range of heights of plant materials in the California annual type rather than clear-cut layers of vegetation. Height of plant materials has intrinsic value in vegetation description when sampled by the point-plot method.

3064. Heady, Harold F., and Lynn Rader. 1958. **Modifications of the point frame.** J. Range Manage. 11(2):95-96.
Abstract: This paper describes several modifications in the design of the original point frame apparatus which make possible rapid and easy sampling of forage cover, ground cover, and height of plant materials in the short, thick cover of California's annual type. The frame and point pins can be used at any angle to the soil surface, and a second set of longer frame legs is useful for sampling tall vegetation. Each individual point pin has its own brake assembly. This facilitates the mechanics of sampling and thereby improves the yield of accurate data. A ruler is located along side each pin and between the horizontal members of the frame. The rulers serve two purposes. One is to measure the height of the pin bit above the soil surface. The second is that they guide the fingers as the pins are pushed into the vegetation, thereby minimizing horizontal movement of the point.

3065. Heady, Harold F., Robert P. Gibbens, and Robert W. Powell. 1959. **A comparison of the charting, line intercept, and line point methods of sampling shrub types of vegetation.** J. Range Manage. 12(4):180-188.
Abstract: The foliage cover of mixed shrubs on an area 100' on a side was completely mapped and sampled by the line intercept and line points. The means and confidence intervals obtained by the 3 methods indicated that all 3 will give reliable estimates of the population mean. Both the transect methods yielded less variable data and will sample adequately with fewer plots and less effort than the charting procedure. The transect procedures gave approximately equal results with the same total length of line for species with ground cover over 3%. However, the line point method took less time and is therefore recommended as the best of the 3 methods to sample areas of shrubs for percentage species composition on a basis of ground cover. Paired transects in the field and on the chart suggested that charting was more accurate for oak than for chamise. This is explained on the basis that canopy boundaries were much more definite for oak than for chamise. It also suggests that charted quadrants in the types of brush sampled gave slightly higher cover than the transects. Distribution of 5% ground cover classes with plots 10x10 feet by charting approximated a normal curve for total cover and chamise on one plot. The distribution of oak and *Ceanothus* on the chamise plot and all species in the live oak plots as determined by intercepts were non-normal by being greatly skewed toward low density classes. The influence of non-normality on sampling and the reliability of inferences drawn from such samples is discussed. Species with ground cover of less than 3% require extremely large samples. The line intercept method sampled these species better than the line point method.

A. H. Murphy

UC Berkeley professor Harold Heady (right) explains mulch plot research to participants in field day, Vassar Pasture, May 1961

3066. Heady, Harold F. 1961. **Ecological research findings on the annual grass type at the Hopland Field Station.** California Forestry and Forest Products Rep. No. 24, School of Forestry, Forest Products Lab., Calif. Agric. Exper. Sta., Berkeley, CA. 4 pp.
Abstract: Output of forage by the annual grass type is strongly influenced by variations in weather and by grazing management practices. The objective of this review was to identify influencing factors so that recommendations could be made for more efficient range management resulting in increased livestock production. Changes in relative and absolute amounts of the different forage species are to a large extent directly correlated with weather fluctuations. Large annual variations in both rainfall and temperature cause the proportion of the different annual species to vary to such an extent that some years are known as good clover years, some as filaree years, and some as grass years. Weight of herbage production at the end of the growing season may differ between years by over 100%. The effects of grazing on annual vegetation is very rapid. Removal of different amounts of plant material showed that there was a positive correlation between amounts of mulch or ungrazed plant material in the fall and botanical composition, forage production, and seasonal growth patterns in the following growing season. Use of forage at a moderate rate and continuous grazing during the winter and spring periods are more likely to give the most

efficient year-in and year-out livestock production.

3067. Heady, Harold F. 1968. **Comprehensive network site description, Hopland.** Tech. Rep. 42, U.S. International Biological Program, Grassland Biome, Natural Resource Ecology Lab., Colorado State Univ., Fort Collins, CO. 12 pp.
***Abstract*:** Describes the Hopland Field Station in terms of location, elevation, size, type of grassland with vegetational categories, periods of growth, weights of production, and response to grazing. Climatic characterization of location with rainfall and temperature variations is include. Soils, exposures, and topography of the area are explained.

3068. Heise, K., A. Merenlender, and G. Giusti. 1996. **Vernal pools in oak woodlands: puddles or unique habitats?** Oaks 'n' Folks 11(2):1-2.
Abstract: This summary defines vernal pools and describes their unique features, including their unique fauna and flora that have developed over centuries of evolution. Habitats where vernal pools still exist in California are often grazed by livestock. Twelve vernal pools greater than $100m^2$ in size on the Hopland R & E Center are characterized by physical factors, plant species, and other biological parameters. Ongoing research is investigating optimum management methods for these resources.

A. H. Murphy

Vernal pools, full after heavy rain, Orchard Pasture, February 1986

3069. Heise, Kerry L., and Adina M. Merenlender. 1999. **Flora of a vernal pool complex in the Mayacamas mountains.** Madrono 46(1):38-45.
Abstract: Vernal pools in the Mayacmas Mountains of southeastern Mendocino County, CA typically occupy topographic depressions related to landslide dams and fissures. A group of pools within a 1290-ha study area range in size from 180 to 3069 m^2, and are located at elevations between 329 and 902 m on slopes of oak woodland and chaparral. *Eryngium aristulatum* Jepson var. *aristulatum* and *Isoetes howellii* Engelm. co-dominate shallow, wide-margined pools and are associated with vernal pool specialist taxa such as *Gratiola, Navarretia, Plagiobothrys*, and *Pogogyne.* Deep, narrow-margined pools are characterized by cosmopolitan wetland taxa such as *Callitriche, Carex, Eleocharis, Juncus*, and *Ranunculus.* Plant surveys conducted in 1996 and 1999 indicate no significant change in species abundance or composition between the two years.

3070. Heise, Kerry L. 2000. **A half century of change to the flora of a hardwood rangeland in northwest California.** Oaks 'n' Folks 15(1):3, 6.
Abstract: A recent inventory of plants occurring on the Hopland R & E Center is compared to early plant inventories conducted in 1954 and 1983. A total of 662 species and infra-specific taxa are now found to occur on Center property. Many introduced species that were absent or sparse in 1954 have since undergone dramatic increases in abundance. Such species include pennyroyal (*Mentha pulegium*), barb goatgrass (*Aegilops triuncialis*), Japanese hedge-parsley (*Torilis arvensis*), big quaking grass (*Briza maxima*), and hedgehog dogtail (*Cynosurus echinatus*). A combination of heavy livestock grazing and establishment of invasive species may have played a role in the disappearance of some 43 species which could not be re-located; a few such species were perhaps removed during intentional vegetative type conversions.

3071. Hilty, Jodi A., and Adina M. Merenlender. 2000. **Faunal indicator taxa selection for monitoring ecosystem health.** Biological Conserv. 92:185-197.
Abstract: Maintaining healthy ecosystems is a prerequisite for conserving biodiversity. The complex nature of ecosystems often necessitates the use of indicator taxa to monitor ecosystem health. However, ambiguous selection criteria and the use of inappropriate taxa have brought the utility of indicator taxa under question. This review compiles existing selection criteria from the literature, evaluates inconsistencies among these criteria, and proposes a step-wise selection process. In addition, 100 vertebrate and 32 invertebrate taxa documented in the conservation science literature as indicators of ecosystem health are examined to assess how well they adhere to the referenced criteria. Few vertebrate taxa fulfill multiple criteria, as most are highly mobile generalists that lack established tolerance levels and correlations with ecosystem changes. Most suggested invertebrate taxa also lack correlations to ecosystem changes, but satisfy other selection criteria. However, invertebrate taxa are often suggested at high taxonomic levels, encompassing many species, making it difficult to measure specific attributes, and potentially including many unnecessary and even inappropriate species.

3072. Holmes, Tyson H., Robert H. Schmidt, and Charles E. Vaughn. 1991. **Response of foliar gallotannins to browsing and drought in blue oak (*Quercus douglasii*) seedlings (Abstract).** Bull. Ecol. Soc. Am. 72(2):144.
Abstract: We are conducting studies on browsing-induced chemical defenses in blue oak seedlings subjected to soil drought. In an initial 2×2 factorial greenhouse experiment, seedlings were browsed by 50% (distal half of each leaf removed) or undamaged either with or without irrigation. Foliar gallotannins declined with browsing ($F = 11.05$, $P = 0.0026$), but showed no response ($F = 1.34$, $P = 0.2582$) to a significant reduction ($F = 35.25$, $P = 0.004$) in soil moisture. This suggests that an initial browsing event may reduce the carbon-based chemical defense capability of these seedlings, contributing to an increased susceptibility to subsequent herbivory.

3073. Huntsinger, Lynn, and James W. Bartolome. 1992. **Ecological dynamics of *Quercus* dominated woodlands in California and southern Spain: a state-transition model.** Vegetatio 99-100:299-305.
Abstract: There are many similarities between Spanish and California *Quercus* woodlands and savanna. Both are located in Mediterranean climate zones, and are used predominantly for livestock grazing. The California overstory is dominated by one or a combination of five *Quercus* species and their hybrids: *Quercus douglasii, Q. agrifolia, Q. wislizenii, Q. lobata*, and *Q. englemannii* (blue, coast live, interior live, valley, and Englemann oaks). In southern Spain and Portugal, *Quercus* woodland overstory is predominantly one or a combination of two *Quercus* species, *Quercus ilex* (holm oak) and *Quercus suber* (cork oak). The underlying natural and semi-natural ecological dynamics of the *Quercus* woodlands of Spain and California are different, and it follows that the management practices employed also differ. The greatest point of contrast between California and Spain is in the

intensity and diversity of management goals and practices. A state-transition model for comparing the ecological dynamics o*f Quercus* woodlands and savanna in California and southern Spain is developed and examined. The highly simplified model is an analytic tool of use in organizing research and developing management practices. States are reached and maintained in different ways in Spain and California, but their appearance and their function in each landscape are quite similar.

3074. Hutchinson, Elmarie S. 1982. **Genetic markers and ecotypic differentiation of *Avena barbata*.** Ph.D. Dissertation, Univ. Calif. Davis. 153 pp.
***Abstract*:** Twelve populations of *Avena barbata* (slender wild oat) were evaluated by 3 criteria to determine if they belong to xeric and mesic ecotypes. The criteria are: physical estimates of moisture in the populations' environments, quantitative-character phenotypes determined by uniform-garden study, and marker genotypes. Seven populations are well described as belonging to a xeric ecotype. Six of these are nearly identical for marker genotype and most quantitative-character phenotypes, but are differentiated into an early flowering biotype (3 southern California populations) and a later-flowering biotype (3 northern California populations). The seventh population has a different marker genotype, but from its quantitative-character phenotypes and the environmental estimates for its site, it is well described as belonging to the xeric ecotype. Five populations having a total of 3 marker genotypes are appropriately classified as belonging to a mesic ecotype. These 5 populations are differentiated into 3 biotypes by the marker genotypes and quantitative-character phenotypes. Marked and consistent differences among these 3 biotypes indicate that they might be separated into different ecotypes on the basis of some environmental variable other than moisture. Results from the sample of populations surveyed suggest that further uniform-garden study of other populations would likely reveal additional biotypes of the mesic ecotype and possibly also others of the xeric ecotype. This study indicates that ecotypic differentiation has been important in the evolution of California populations of *A. barbata*, as it acts to bring about finer and finer adaptation of genotypes to local environments.

3075. Hutchinson, Elmarie S. 1984. **Seed size and quantitative characters in *Avena barbata*.** Heredity 52(1):25-33.
Abstract: Seed size differences in *Avena barbata* are of two sorts. First, there is a seed size dimorphism (floret position) such that half of the seeds on every plant are larger. Second, the characteristic seed sizes of certain populations are significantly larger than those of other populations. This study reports relationships between seed size and quantitative characters at very early, intermediate, and late stages of the plant's life cycle: young seedlings of *Avena barbata* grown from smaller seeds are smaller than seedlings grown from larger seeds. Larger seeds do not produce plants that are larger at later stages if the seed size difference is determined by floret position with the same genotype. Larger seeds do produce plants that are larger at later stages if the seed size difference characterizes populations having different genotypes at many loci.

3076. Jain, S. K., and K. N. Rai. 1980. **Population biology of Avena. VIII. Colonization experiment as a test of the role of natural selection in population divergence.** Am. J. Bot. 67(9):1342-1346.
Abstract: Two wild oat species, *Avena fatua* and *A. barbata*, have become successful colonizers of the grasslands in California within the past 200 years. Population studies have led to several interesting findings, namely 1) a pattern of regional differentiation within Central California in which a large region in the Central Valley showed virtually no genetic polymorphism; 2) a highly patchy distribution of polymorphism within the Bay and North Coast Regions, and 3) a highly localized cline along the xeric-mesic gradient. In this study, artificially founded colonies of *Avena barbata* were utilized in two experiments in order to examine the role of natural selection in the evolution of regional differentiation in Central California. One experiment involved a total of 41 colonies founded in three different areas and scored over a 10-year period; these colonies, started with known genotypes, showed that although both Valley and Bay region genotypes establish successful colonies, their relative survivorship and fecundity suggests weak selective forces consistent with those predicted from the observed patterns in natural populations. The second experiment involved two localities, representing two climatic regimes of temperature, in each of which 10 colonies were started from identical seed sources. These colonies also showed relatively higher fitness of the genotypes matching with those sampled from the Valley and Coastal regions, respectively, again in line with their regional patterns of distribution. Colonization experiments appeared to be useful even as short-term *in situ* tests of certain specific evolutionary hypotheses on the role and intensity of natural selection.

3077. Jones, Milton B., and Horton M. Laude. 1961. **Relationships between sprouting in chamise and the physiological condition of the plant.** Calif. Agric. 15(6):9-10.
Abstract: Sprout growth in chamise was measured after cutting the brush in January, March, May, July, September, and November 1957. The physiological condition of the plant was evaluated at each date of cutting by chemical analysis of plant fraction and by determinations of growth rate, twig moisture, solid moisture, and prevailing temperatures. Growth measurements were continued throughout the year following cutting. In this species the root fraction yielded the best samples for analysis, being more free of interspersed dead tissue than either the stems or crown. Chemical analyses revealed a significant seasonal trend in the content of starch, total sugars, glucose, protein, calcium, potassium, and phosphorus. Of these, starch exhibited the greatest change. Twig moisture also reflected a pronounced seasonal difference. A sharp rise in twig moisture immediately precedes a rapid increase in growth rate which is associated with an abrupt decline in the stored starch reserves. The height of sprouts following spring growth the year after cutting was, in general, inversely related to twig moisture at the time of cutting and directly related to stored starch content of the root at the time of treatment. It is suggested that twig moisture and level of stored starch reserves may be used to indicate, at the time of treatment, the subsequent sprouting potential.

3078. Jones, Milton B., C. M. McKell, and S. Sherwood Winans. 1963. **Effect of soil temperature and nitrogen fertilization on the growth of soft chess (*Bromus mollis*) at two elevations.** Agronomy Journal 55:44-46. *Also published in* Calif. Agric. 17(5):12-14, May 1963.
Abstract: The results of this study support the view that nitrogen fertilization increases winter growth of grasses; however, definite limitations are indicated. When mean winter soil temperatures were below 45°F., growth was very slow; and nitrogen fertilization increased growth relatively little. Grass fertilized with nitrogen showed the greatest increase in growth, compared with unfertilized grass, when the temperature ranged from 47° to 55°. When the temperature went above 55°, the difference between growth rates of fertilized and unfertilized grass decreased. Apparently some factor in the physiological process other than the supply of ammonia was the most limiting to plant growth below 47° and above 55° since the application of urea increased the growth rate relatively little outside these limits. At comparable temperatures plant growth was more rapid during April and May, when days were longer, than during January and February. Several factors were involved: 1) The days were longer, 2) the light intensity was greater because the sun was farther north and less cloudy weather occurred, and 3) plant development was more advanced.


Don Torell

Agronomist Milton Jones in HFS greenhouse, February 1968

3079. Jones, Milton B., Charles E. Vaughn, and Robert S. Harris. 1976. **Critical Ca levels and Ca/Mg ratios in *Trifolium subterraneum* grown on serpentine soil.** Agron. J. 68(5):756-759.
Abstract: Serpentine soils are known to have a low Ca/Mg ratio and respond to applied Ca in many instances. To assist in assaying the Ca status of these soils, we determined the effect of growth stage, plant part, and defoliation treatment on the critical Ca concentrations and Ca/Mg ratios in subclover growing in potted serpentine soil of the Henneke series, a lithic Argixeroll. One of the six rates (0, 200, 400, 800, 1,600 and 3,200 ppm) of Ca as $CaSO_4$ and uniform rates of P, K, S, and Mo were applied to each pot and the soil was mixed uniformly and planted to Geraldton subclover (*Trifolium subterraneum*). On one set, leaves were removed 61, 85, and 114 days after planting. On a second set, leaves were removed on days 85 and 114, and the third set grew without clipping until day 114. Critical Ca percentages in the three youngest leaves ranged from 0.55% to 0.69%, with no consistent trend due to growth stage or number of times the plant had been defoliated. In old leaves, critical Ca levels ranged from 0.81% to 1.47% and were higher for 114-day old plants than for 85-day old plants. The more often the plant was defoliated, the lower the critical level in old leaves. There was no significant difference between young and old stem tissue in critical Ca levels: 0.30% to 0.38% Ca. Defoliation did not induce consistent change. Critical Ca/Mg ratios in young leaves increased from 0.42 to 0.60 between plant ages of 61 and 85 days, whereas no significant change occurred from day 85 to day 114. With plants defoliated for the third time at day 114 the critical Ca/Mg ratio was 0.36, although at first and second clippings their critical ratios were 0.60. Calcium/Mg ratios were similar in young and old leaves. In young stems the critical Ca/Mg ratios on day 114 for the first, second, and third clippings were respectively 0.48, 0.39, 0.27, and 0.18. It was concluded that percent Ca and Ca/Mg ratios in new and old stems were insensitive as measures of Ca status since these values changed less in stem than in leaves over a wide range of Ca levels. Percent Ca in young leaves was the best measure of Ca status because critical values varied less due to stage of growth or clipping treatment than did percent Ca in old leaves or Ca/Mg ratios in young or old leaves.

3080. Kepner, Richard E., Barbara O. Ellison, Michael Breckenridge, Guy E. Connolly, Steven C. Madden, and Carlos J. Muller. 1974. **Volatile terpenes in California bay foliage. Changes in composition during maturation.** Agric. and Food Chem. 22(5):781-784.
Abstract: Volatile components of leaves of California bay, *Umbellularia californica*, isolated by steam distillation and ether extraction, were separated by column and preparative gas chromatography. Individual components were characterized by infrared and mass spectroscopy, and by determination of Kovats indices. Twenty-one compounds were identified, the ones present in greatest abundance being umbellulone, 1,8-cineole, α-terpineol, sabinene, terpinen-4-ol, and methyl eugenol. The compositions of volatile components in the essential oils from California bay new leaf growth and year-old growth were investigated over a growing season. A general trend observed in the analyses of the old growth samples was a continual decrease in the level of volatile terpenes from the first sampling in early April until the middle of June, followed by an increase in amounts until the termination of the study in August. The amounts of all components in new leaf growth, initially very small relative to the amounts of the same components in mature growth, increased slowly through the first four weeks and then rapidly thereafter to the point where most components were, by the end of the study, present in greater concentration in new than in old growth. The implications of these results relative to the very low palatability of California bay for browsing ruminants are discussed.

3081. Kloss, Susan A. 2000. **Geographic patterns of phenotypic variation in water relations traits in Sierran populations of California blue oak (*Quercus douglassii*).** Ph.D. Dissertation, Univ. Calif. Berkeley. 148 pp.
Abstract: This study characterized the distribution of genetic variation in California blue oak populations using a greenhouse experiment, and an experiment that compared the data from the experimental treatments with data collected from the same populations in a common garden and from the field sites. This study developed understanding of how genetic variability is distributed between and within populations of California blue oaks. Phenotypic variation in water relations traits of 6 populations (2 populations from high precipitation areas, 2 from medium precipitation areas, and 2 from low precipitation areas) of California blue oak were compared. Seedlings from each of the populations were subjected to 3 different watering treatments in a greenhouse experiment, and growth and biomass production of each population was analyzed to determined whether there were significant differences between populations. There were significant differences among populations in growth and biomass production characteristics, specifically those related to seedling size, which significantly correlated with the water availability gradient. Significant among-treatment differences indicated at least low levels of plasticity, although there were no significant treatment × population interactions which would have suggested high levels of plasticity. Leaves from the experimentally treated seedlings were also analyzed for morphological characteristics and levels of wax biosynthesis. There were significant differences among populations in leaf shape; leaves from populations in areas of high precipitation were longer and more linear than leaves from populations in areas of low precipitation. Leaves from juveniles in common gardens showed significant among-population differences in leaf size, but not shape; in addition, amount of wax deposition was significantly different among populations. These traits were all significantly correlated with the water availability gradient. In adult trees from field sites, only leaf specific mass was significantly different between populations, and was also significantly correlated with the water availability gradient.

3082. Koenig, Walter D., and Johannes M. H. Knops. 1997. **Patterns of geographical synchrony in growth and reproduction of oaks within California and beyond.** Pp. 101-108 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: We measured patterns of spatial synchrony in grown and reproduction by oaks using direct acorn surveys, published data on acorn production, and tree-ring chronologies. The two data sets involving acorn production both indicate that acorn crops are detectably synchronous over areas of at least 500 to 1,000 km not

only within individual species but among species that require the same number of years to mature acorns. Although no tree-ring data are available for California oaks, growth patterns among oaks elsewhere are statistically correlated between sites up to 2,500 km apart. These results indicate that both tree growth and acorn production patterns covary over large geographic scales and support the hypothesis that large-scale weather patterns play an important role in determining these life-history parameters of California oaks. They also have important implications for the population biology of wildlife that live in California's oak woodlands.

Guy E. Connolly

Scrub oak acorns, August 1974

3083. Koenig, Walter D., Dale R. McCullough, Charles E. Vaughn, Johannes M. H. Knops, and William J. Carmen. 1999. **Synchrony and asynchrony of acorn production at two coastal California sites.** Madrono 46(1):20-24.

Abstract: We measured annual acorn production of oaks *Quercus* spp. at Hastings Reservation and at Hopland R & E Center, located 320 km apart in the outer coast ranges of California, for 16 years between 1982 and 1997. Of the 3 species measured at both sites, acorn production by *Quercus lobata* (valley oak) and *Quercus douglasii* (blue oak) was significantly correlated between sites, whereas acorn production by *Quercus kelloggii* (California black oak) was not. Both *Q. lobata* and *Q. douglasii* acorn production was significantly correlated with mean April temperatures and rainfall at their respective localities, but more closely with April temperatures at Hastings and with rainfall at Hopland. Synchrony in acorn production between *Quercus* spp. requiring one year to mature acorns was significantly greater than among those requiring two years to mature acorns. The geographic extent of the populations producing acorn crops synchronously differs between species, but in some cases may extend over distances of at least several hundred kilometers.

3084. Koenigs, Robert L. 1977. **Environmental gradients influencing vegetation on a serpentine soil. I. Principal components analysis of vegetation data. II. Chemical composition of foliage and soil.** Ph.D. Dissertation, Univ. Calif. Davis. 67 pp.

Abstract: I. Based on composition of the vegetation, 40 sampling sites were objectively divided by an agglomerative method of cluster analysis into 2 groups ("cypress" and "non-cypress" stands) such that significant differences in means of environmental variables were found. *Cupressus sargentii* was limited to and *Arctostaphylos viscida* was most abundant in the cypress stands which were located in more mesic sites with lower Ca in the subsurface soil. Principal components were extracted from the vegetation data in each group of stands. Simple and partial correlations of environmental variables with each PC were calculated in order to determine whether underlying environmental gradients, possibly responsible for patterns in the vegetation, could be discerned. Within the cypress stands, a moisture gradient with components of elevation and water storage capacity appears to be the most important gradient. However, elevation would appear to have too narrow a range to be effective. No measured variable correlated with elevation was found to replace it. *A. viscida* was more abundant at higher elevations and greater water storage capacities. *C. sargentii* was most abundant at the opposite end of the gradient. The only other hypothesized gradients in the cypress stands appear to be related to drainage. There were no soil chemistry gradients of much importance found. Within the non-cypress stands, relationships with environmental variables are not as good as within the cypress stands, perhaps due to greater variability causing linear methods of analysis to be inapplicable. Soil Ca is the most important gradient for both the shrubby species and the understory species: *Adenostoma fasciculatum* and *Garrya congdonii* are most abundant at the high end while *Ceanothus jepsonii*, *Quercus durata*, *Bromus laevipes*, and *Sisyrinchium bellum* have the highest loadings at the opposite end of the gradient. There are numerous factors that could affect species distributions, thereby obscuring relationships with environmental gradients. Historical factors (such as fires), interspecific interactions, and dispersal abilities are such factors. It is significant that better relationships were found where the vegetation was less complex (i.e. Cypress stands). The effect of stand age could not be properly evaluated in this study due to the poor distribution of ages, but it does appear that age has little effect on the vegetation in older stands. More samples with less intensive sampling would also have been desirable.

II. Chemical composition of leaf tissue was determined for 4 species growing on serpentine soils in order to compare amounts of elements taken up, relationships between leaf and soil chemistry, and responses of species to both the internal (leaf) and external (soil) chemical environment. Micronutrient toxicities (Ni, Cr, Co) do not appear to be a problem, at least to the dominant species in the area. Molybdenum concentrations were below detectable limits (.2 ppm). Potassium has the least interspecific variability and the highest accumulation ratio for all species. Calcium has the greatest variability and the next highest accumulation ratio. The average accumulation ratio for Mg exceeds 1.0 only in the case of *A. fasciculatum*, the same species for which the average Ca/Mg ratio is less than 1.0. Leaf chemistry is better correlated with species variables more often than soil chemistry and is not always well correlated with soil chemistry. Where there are significant correlations they are as expected; i.e., positive with the same cation and negative with others, presumably indicating competition for uptake. Leaf Ca is the cation most consistently correlated with soil chemistry and in the case of *Q. durata* is negatively correlated to soil Ca. It is proposed that the demand for Ca by of *A. fasciculatum* reduced the amount available to *Q. durata*, which in turn caused increased Mg uptake and poorer growth in *Q. durata*. Leaf Mg in *Q. durata* is negatively correlated with *Q. durata* cover and positively with *A. fasciculatum* cover. *A. fasciculatum* occurs in the higher Ca sites, has the lowest Ca levels in its leaves, and is highly, positively correlated with leaf Ca, which is positively correlated with soil Ca. These facts together with the Mg accumulation ratio and Ca/Mg ratio indicate that *A. fasciculatum* is least adapted to serpentine conditions and is the best indicator of a favorable Ca status. Where it does occur, Ca is more abundant where *C. sargentii* cover is higher and *A. viscida* is less dense. *A. viscida* is the only species having variables negatively correlated with leaf or soil Ca or Ca/Mg ratio. Potassium, both leaf and soil, is correlated only with *C. sargentii* and *A. viscida* variables. Within the cypress stands, the height of both species is negatively correlated with soil K and positively correlated with leaf K. Exchangeable soil is obviously a poor measure of K availability to these species.

3085. Koenigs, Robert L., William A. Williams, and Milton B. Jones. 1982. **Factors affecting vegetation on a serpentine soil. I. Principal components analysis of vegetation data.** Hilgardia

50(4):1-14.
Abstract: Vegetation of 40 sample stands on serpentine soils was analyzed and used to indicate conditions that might limit the establishment of annual range species. Two groups of stands, "cypress" and "non-cypress" were defined by cluster analysis. Stands with *Cupressus sargentii* also contained *Arctostaphylos viscida* and occurred on mesic sites with lower Ca in the sub-surface soil. Stands without *C. sargentii* usually contained *Adenostoma fasciculatum* and *Quercus durata* and occurred on the drier sites with higher Ca. Principal component analysis was carried out on the vegetation data in each group of stands, and simple and partial correlations were calculated between principal components and environmental variables. A moisture gradient within the cypress stands was associated mainly with the water storage capacity of the soil. *Cupressus sargentii* was more abundant at lower water storage capacities (and at lower elevations) while *Arctostaphylos viscida* was most abundant at the opposite end of the gradient. No correlations were found with soil chemical analyses. The relations between principle components and environmental variables were less apparent within the non-cypress stands. *Adenostoma fasciculatum* and *Garrya congdonii* were most abundant where Ca contents in the soil were high while *Ceanothus jepsonii, Quercus durata, Bromus laevipes*, and *Sisyrinchium bellum* were most abundant at the opposite end of the gradient.

3086. Koenigs, Robert L., William A. Williams, Milton B. Jones, and Arthur Wallace. 1982. **Factors affecting vegetation on a serpentine soil. II. Chemical composition of foliage and soil.** Hilgardia 50(4):15-26.
Abstract: Ion concentrations in the foliage of *Adenostoma fasciculatum*, *Arctostaphylos viscida*, *Cupressus sargentii*, and *Quercus durata* were determined and correlated with the abundance and plant size of these indigenous species and with soil concentrations of these ions. The species differed most in Ca concentration, and only slightly in K concentration. In all species the accumulation ratios were greater for K (meq / 100 g in plant / meq 100 g in soil) than for any other element; the next highest was for Ca. The accumulation ratio for Mg exceeded 1.0 only in *Adenostoma fasciculatum*. *Adenostoma fasciculatum* occurred mostly on soils with a relatively high Ca content, had the lowest Ca concentration in its leaves, was most abundant where Ca concentration in its leaves was highest, and had the highest Mg accumulation ratio. These facts indicate that this species is least adapted to serpentine conditions. *Cupressus sargentii* was well-adapted to the conditions found in this study. This species accumulated Ca and excluded Mg resulting in an average Ca / Mg ration in its leaves of 1.44, while the soil it grew on had an average Ca / Mg ratio of 0.08. Percentage cover and density of *Arctostaphylos viscida* were the only variables to be correlated negatively with Ca of Ca / Mg ratio. This seems to indicate that *A. viscida* has low optima for Ca and the Ca / Mg ratio. There was no evidence of toxicity of Ni, Cr, or Co. Molybdenum concentrations in leaf tissue were below detectable limits (0.2 ppm). Introduced species should have a better chance within the sites containing non-cypress stands, and their chances within the sites containing non-cypress stands should be best where *Adenostoma fasciculatum* and *Garrya congdonii* are most abundant because of the more favorable Ca status of the soil supporting them.

3087. Lancaster, Donald L. 1977. **Ecological significance of nitrate uptake and reduction by three annual grass species.** Ph.D. Dissertation, Univ. Calif. Davis. 46 pp.
Abstract: Nitrate uptake and reduction was investigated in intact seedlings of wild oats (*Avena*), soft chess (*Bromus mollis*), and annual ryegrass (*Lolium multiflorum*) at 20 and 30 days of age. Cumulative NO_3 uptake was characterized by an initial slow rate followed by an increase in uptake at 20 and 30 days of age. After the initial lag phase, cumulative uptake from each nitrate concentration studied was a straight line function for each of the 3 species. Nitrate uptake as a function of concentration was curvilinear describing a Langmuir absorption isotherm. This relationship suggests a carrier mediated transport system. At 20 days of age *Lolium multiflorum* seedlings were capable of absorbing 4 times as much nitrate as *Bromus mollis* seedlings and 4.5 times as much nitrate as *Avena fatua* seedlings from NO_3 concentrations above 0.10 mM. The Km values at 20 days suggest that *Bromus mollis* seedlings were capable of more efficient uptake at low nitrate concentrations followed by *Avena fatua* and *Lolium multiflorum* seedlings. At 30 days of age all 3 species demonstrated similar maximal uptake rates with *Lolium multiflorum* and *Bromus mollis* seedlings having similar uptake at equal concentrations, and *Avena fatua* seedlings being least capable of uptake from low nitrate concentrations. At 20 days of age *Bromus mollis* seedlings reduced significantly more nitrate that *Lolium multiflorum* and *Avena fatua* seedlings while at 30 days of age *Avena fatua* seedlings were capable of the greatest nitrate reduction followed by *Lolium multiflorum* and *Bromus mollis* seedlings.

3088. Laude, Horton M., Milton B. Jones, and William E. Moon. 1961. **Annual variability in indicators of sprouting potential in chamise.** J. Range Manage. 14(6):323-326.
Abstract: The annual variability in chamise (*Adenostoma fasciculatum*) growth and in starch reserves in the root was related to environmental conditions over a 4-year period. The starch trend, date of growth initiation, and twig moisture level varied sufficiently in relation to prevailing moisture and temperature conditions as to render unreliable the scheduling of control treatments by calendar date. Reduced vigor of sprouting is associated with treatments applied in the late spring and early summer when the high winter and early spring level of root starch reserves has been depleted. This period of low starch follows the onset of spring growth by 4 to 6 weeks. It is suggested that the effectiveness of treatments to suppress chamise would be increased by scheduling them during this period of low stored reserves.

3089. Leonard, Oliver A., and R. J. Hull. 1965. **Translocation relationships in and between mistletoes and their hosts.** Hilgardia 37(4):115-153.
Abstract: Studies of translocation between mistletoes and their host trees were conducted under natural conditions in various California locations. Both dwarf (*Arceuthobium* spp.) and green (*Phoradendron* spp.) mistletoes were studied. Various labeled materials were used, including $^{14}CO_2$, several ^{14}C-labeled herbicides, and ^{32}P and ^{35}S (as phosphate and sulfate, respectively). Translocation in green mistletoes differed from that in dwarf mistletoes. In the green species, labeled assimilates and ^{32}P were transported basipetally into the endophytic systems. However, label did not move from the green mistletoes into the host branches.

3090. Lindow, Steven E. 1995. **Integrated control of frost injury, fire blight, and fruit russetting of pear using biological and cultural methods.** Annual report to California Pear Research Board, Univ. Calif. Berkeley. 7 pp. + tables & figures.
Abstract: Studies were made of the concentrations of the biological control agent *Pseudomonas fluorescens* strain A506 (Blightban A506) that were needed to establish population sizes on pear flowers and young fruit sufficiently large to control fire blight disease, and to reduce the incidence of fruit russetting and frost damage. In addition, the frequencies at which different concentrations of strain A506 need be applied to achieve these objectives was also measured. Similar population sizes of strain A506 were achieved when strain A506 was applied at the label rate (10^8 cells/ml) as well as when this strain was applied 3 times at 50% this dosage as well as 3 times at 10% this dosage. Similar population sizes of the biological control agent were achieved on most trees where strain A506 was applied at 50% the label rate but at twice the number (6 times) of recommended

applications; in some studies the population size of strain A506 was higher than when sprayed 3 times with the label rate. The incidence of frost damage to fruit at harvest was reduced by all applications of strain A506 but the greatest degree of reduction of frost damage was achieved on trees treated 6 times with 50% the label rate. Similarly, the severity of fruit russetting on trees treated with strain A506 was reduced in all cases but the greatest degree of reduction occurred on trees treated 6 times with the biological control agent. While shipments of Blightban A506 by the commercial supplier were of relatively low quality early in the 1995 growing season, a substantial fraction of the flowers of the trees treated with this material were colonized by this bacterium. In large commercial tests, the incidence of both frost damage and fruit russetting was reduced by the application of Blightban A506. The largest reductions in the incidence of frost damage and the severity of fruit russetting occurred on trees treated 6 times with 50% the label rate of Blightban A506. Fruit russetting was greatly reduced y the applications of various nitrogen-containing compounds. Similar reductions in fruit russetting were obtained by applications of ammonium sulfate, urea, or calcium nitrate, each at 400 ppm nitrogen. In 1995, russetting was reduced to the greatest extent on trees receiving 2 or more applications of a given concentration of each of these nitrogenous compounds. Probably because of the frequency of early-season rains, the application of nitrogen compounds 2 or 3 weeks following full-bloom reduced the severity of fruit russet more than earlier sprays.

Mendocino Co. Extension advisor Bruce Bearden prunes newly planted pear trees, Niderost Pasture, Winter 1989

3091. Lindow, Steven E. 1996. **Integrated control of frost injury, fire blight, and fruit russetting of pear using biological and cultural methods.** Annual report to California Pear Research Board, Univ. Calif. Berkeley. 18 pp.

Abstract: Studies were made of the concentrations of the biological control agent *Pseudomonas fluorescens* strain A506 (Blightban A506) that were needed to establish population sizes on pear flowers and young fruit sufficiently large to control fire blight disease, and to reduce the incidence of fruit russetting and frost damage. In addition, the frequencies at which different concentrations of strain A506 need be applied to achieve these objectives was also measured. Similar population sizes of strain A506 were achieved when strain A506 was applied at the label rate (10^8 cells/ml) as well as when this strain was applied 3 times at 50% this dosage as well as 3 times at 10% this dosage. Similar population sizes of the biological control agent were achieved on most trees where strain A506 was applied at 50% the label rate but at twice the number (6 times) of recommended applications; in some studies the population size of strain A506 was higher than when sprayed 3 times with the label rate. The population size of strain A506 on trees was substantially lower when this strain was tank mixed with Terramycin or when Terramycin was applied immediately after application of strain A506 than on trees on which Terramycin was not applied for a few days after inoculation. The severity of fruit russetting on trees was reduced in many treatments in which strain A506 was applied to trees. The populations of strain A506 on trees treated by growers in large commercial tests were measured. The highest proportion of flowers that were colonized were observed shortly after application of the antagonistic bacterium (about 80% of the flowers on average), while the proportion of flowers that were colonized on subsequent samplings decreased with time since the last spray (presumably since flowers that were not open at the time of spraying had opened in the interim and were not yet heavily colonized. Fruit russetting was greatly reduced by the applications of various nitrogen-containing compounds. Similar reductions in fruit russetting were obtained by applications of ammonium sulfate, urea, or calcium nitrate, each at 400 ppm nitrogen. The control of fruit russet by application of nitrogen compounds was additive to that conferred by removal of orchard cover crops.

3092. Lindow, Steven E. 1997. **Integrated control of frost injury, fire blight, and fruit russetting of pear using biological and cultural methods.** Annual report to California Pear Research Board, Univ. Calif. Berkeley. 6 pp. + tables & figures.

Abstract: Studies were made of the concentrations of the biological control agent *Pseudomonas fluorescens* strain A506 (Blightban A506) that were needed to establish population sizes on pear flowers and young fruit sufficiently large to control fire blight disease, and to reduce the incidence of fruit russetting and frost damage. In addition, the frequencies at which different concentrations of strain A506 need be applied to achieve these objectives was also measured. Similar population sizes of strain A506 were achieved when strain A506 was applied at the label rate (10^8 cells/ml) as well as when this strain was applied 3 times at 50% this dosage as well as 3 times at 10% this dosage. The highest population sizes were observed on trees where strain A506 was applied at 50% the label rate but at twice the number (6 times) of recommended applications. Application of strain A506 with the silicon-based surfactant Breakthru resulted in slightly higher population than on trees in which the bacterium was applied in water alone. The population size of strain A506 on trees was substantially lower when this strain was tank mixed with Terramycin. Population sizes were also lower than on trees on which Terramycin was not applied when Terramycin was sprayed onto A506-treated trees within about 3 days after inoculation. The severity of fruit russetting on trees was reduced in many treatments in which strain A506 was applied to trees. A large-scale survey of resistance to streptomycin, copper, and Terramycin was conducted on strains of *Erwinia amylovora* collected from 39 different orchards throughout California. No strains were resistant to either Terramycin (oxytetracycline) or copper. In many orchards, all strains were sensitive to streptomycin. On average, only about 18% of the strains tested were resistant to streptomycin. In some orchards a small percentage of streptomycin resistant strains were observed, while in a few orchards, all of the strains were streptomycin resistant. Most streptomycin-resistant strains of *E. amylovora* were resistant to over 1000 ppm streptomycin, and resistance in these strains is presumably conferred by chromosomal mutations. In a few orchards, strains were recovered that were resistant to only about 120 ppm streptomycin, and resistance is probably due to plasmid-borne streptomycin resistance genes. The incidence of streptomycin resistance in *E. amylovora* populations has thus not increased substantially in the 20 years since the last surveys were conducted,

and is much lower than most growers believe. Fruit russetting was greatly reduced by the applications of various nitrogen-containing compounds. Similar reductions in fruit russetting were obtained by applications of ammonium sulfate, urea, or calcium nitrate, each at 400 ppm nitrogen. The control of fruit russet by application of nitrogen compounds was additive to that conferred by removal of orchard cover crops.

3093. Lindow, Steven E., Caroline Desurmont, Rachel Elkins, Glenn McGourty, Ellen Clark, and Maria T. Brandl. 1998. **Occurrence of indole-3-acetic acid-producing bacteria on pear trees and their association with fruit russet.** Phytopathology 88(11):1149-1157.
Abstract: A relatively high percentage of epiphytic bacteria on pear leaf and fruit surfaces had the ability to produce indole-3-acetic acid (IAA) in culture media supplemented with tryptophan. While over 50% of the strains produced at least small amounts of IAA in culture, about 25% of the strains exhibited high IAA production as evidenced by both colorimetric and high-performance liquid chromatography analysis of culture supernatants. A majority of the strains that produced high amounts of IAA were identified as *Erwinia herbicola* (*Pantoea agglomerans*), while some strains of *Pseudomonas syringae, Pseudomonas viridiflava, Pseudomonas fluorescens, Pseudomonas putida*, and *Rahnella aquaticus* that produced high amounts of IAA also were found on pear. Fruit russetting was significantly increased in 39 out of 46 trials over an 8-year period in which IAA-producing bacteria were applied to trees compared with control trees. A linear relationship was observed between fruit russet severity and the logarithm of the population size of different IAA-producing bacteria on trees in the 30 days after inoculation, when normalized for the amount of IAA produced by each strain in culture. On average, the severity of fruit russet was only about 77% that on control trees when trees were treated at the time of bloom with *Pseudomonas fluorescens* strain A506, which does not produce IAA. Both total bacterial populations on pear in the 30-day period following full bloom and fruit russet severity varied greatly from year to year and in different commercial orchards over a 10-year period. There was a strong linear correlation between the logarithm of total bacterial population sizes and fruit russet severity.

3094. Lindow, Steven E. 1998. **Integrated control of frost injury, fire blight, and fruit russetting of pear using biological and cultural methods.** Annual report to California Pear Research Board, Univ. Calif. Berkeley. 4 pp. + tables & figures.
Abstract: Studies were made of the concentrations of the biological control agent *Pseudomonas fluorescens* strain A506 (Blightban A506) that were needed to establish population sizes on pear flowers and young fruit sufficiently large to control fire blight disease, and to reduce the incidence of fruit russetting and frost damage. In addition, the frequencies at which different concentrations of strain A506 need be applied to achieve these objectives was also measured. Similar population sizes of strain A506 need be applied to achieved when strain A506 was applied at the label rate (10^8 cells/ml) as well as when this strain was applied 3 times at 50% this dosage as well as 3 times at 10% dosage. The highest population sizes were observed on trees where strain A506 was applied at 50% the label rate but at twice the number (6 times) of recommended applications. Application of strain A506 with the silicon based surfactant Breakthru resulted in slightly higher population than on trees in which the bacterium was applied in water alone. The population size of strain A 506 on trees was somewhat lower when this strain was tank mixed with Terramycin. Populations of strain A506 were substantially lower when this strain was tank mixed with Dithane. Similar results were observed in tests in commercial orchards in which Dithane was tank mixed. Population sizes of strain A506 were not significantly depressed on trees on which Terramycin was sprayed onto A506-treated trees, even if application was made within 1 hour of inoculation. The severity of fruit russetting on trees was reduced in many treatments in which strain A506 was applied to trees. Fruit russetting was greatly reduced by the applications of 400 ppm nitrogen in the form of ammonium sulfate in bloom-time sprays.

3095. Lindow, Steven E. 1999. **Management of frost injury, fire blight, and fruit russetting of pear using biological and cultural methods.** Annual report to California Pear Research Board, Univ. Calif. Berkeley. 7 pp. + tables & figures.
Abstract: Both the total number of indigenous bacteria in buds as well as the proportion of those bacteria that were "internal" to pear tissue varied greatly between orchards. Total indigenous bacterial populations associated with pear in the early spring in 1999 was generally substantially lower than in other years. The fraction of the total bacterial population associated with pear samples that was "internal" varied from about 5% in a Sacramento orchard to about 30% in a Lake County orchard. Such superficial populations are thus probably strongly influenced by weather conditions in the spring. Bacterial populations were relatively low in buds in the spring of 1999, the applications of eradicant bactericides before bloom did not further lower bacterial populations in most cases except Kocide 101 applied with a penetrating surfactant. Application of strain A506 with the silicon-based surfactant Breakthru resulted in 3-fold higher populations than on trees in which the bacterium was applied in water alone. The severity of fruit russetting on trees was reduced in treatments in which strain A506 was applied to trees. The population size of strain A506 in pear flowers throughout the spring increased greatly with increasing concentrations of surfactant in which the bacteria were applied in a single application before bloom as well as with the age of the pear tissues at which the single inoculation was made. Importantly, the population size of strain A506 on flowers in the spring increased to over 10^6 cells/spur and 10^7 cells/spur on trees that were inoculated only a single time at "first bloom" with Blightban A506 in 0.1% or 0.5% Breakthru respectively. The population sizes of strain A506 on flowers in trees receiving a single application of Blightban A506 in a high rate of surfactant before bloom was much higher throughout the spring than on trees which received weekly application of the same amount of Blightban A506. This exciting result suggests strongly that we should be able to greatly reduce the number of applications of the bacterium by applying it early in the season with a penetrating surfactant. In addition, by applying the bacterium only once early in the early spring before applications of Dithane and Terramycin and other pesticides are subsequently made to trees, we can avoid potential problems with compatibilities off the bacterium with these other pesticides.

3096. Longhurst, William M. 1956. **Stump sprouting of oaks in response to seasonal cutting.** J. Range Manage. 9(4):194-196.
Abstract: On many of California's foothill ranges there is a definite shortage of browse for both livestock and deer. This study was designed to investigate the possibilities of producing stump sprout browse from oaks by cutting trees monthly over a 1-year period. Four of the dominant species of oaks in the area were tested: blue oak (*Quercus douglasii*) and black oak (*Q. kelloggii*) deciduous species, and scrub oak (*Q. dumosa*) and interior live oak (*Q. wislizenii*) which are evergreen species. The evergreen species generally produced more sprouts than did deciduous oaks, and showed less seasonal response. Of the two deciduous species, black oak was the more vigorous sprouter. The evergreen oaks showed considerably more resistance to heavy browsing by deer and sheep. From a management standpoint, it appears that it would be best to cut interior live oak and scrub oak for stump sprouts. They are less sensitive to the season of cutting than the deciduous species and are better able to withstand heavy browsing.

3097. Maarse, Henk, and Richard E. Kepner. 1970. **Changes in composition of volatile terpenes in Douglas fir needles during**

maturation. Agric. and Food Chem. 18(6):1095-1101.
Abstract: The compositions of the volatile terpenes in Douglas fir new tip growth and in year-old needles were investigated over a growing season using a simultaneous steam distillation-extraction method and direct vapor analysis. The results demonstrate the almost complete absence of acyclic oxygenated monoterpenes and *cis*-ocimene in the new tip growth as it first appears, with the gradual increase in concentration of these components as the growth matures. The cyclic oxygenated monoterpenes are immediately present in the new growth in amounts equal to those in year-old growth and show little seasonal variation in either young or old growth. The effects of fertilization with urea vs. gypsum on the volatile terpene compositions and the possible relationship of the terpene compositions of the new tip growth to the greater palatability of this growth to browsing ruminants are discussed briefly.

3098. Marshall, D. R., and S. K. Jain. 1969. **Genetic polymorphism in natural populations of *Avena fatua* and *A. barbata*.** Nature 221:276-278.
Abstract: This reports the results of an extensive survey for polymorphism in *Avena* populations in California. The primary aim of the survey was to obtain comparative data on geographical variation in the patterns of polymorphism is *A. fatua* and *A. barbata* and to ascertain how such variation relates to climatic variables, the relative abundance of the two species, and other factors. Samples of 100 - 200 plants were collected from nearly 200 sites in California by taking all plants within a central area at each site. Among sites included and illustrated on a map of the state are Hopland. All samples were scored for the relative proportions of the two species and for four qualitative traits: color of lemma (black or gray); pubescence of the lemma, and pubescence of leaf sheath and node. Samples of *A. fatua* were clearly polymorphic at most sites. In contrast, *A. barbata* was monomorphic in the Central Valley, with one exception. In the region including Hopland, *A. barbata* often showed a low degree of polymorphism with a few highly polymorphic sites. We postulate that differences in the geographical patterns of polymorphism between the two species can be attributed to the differences in their adaptive strategies and relative abundance.

3099. McClaran, Mitchel P. 1987. **Yearly variation of blue oak seedling emergence in northern California.** Pp. 76-78 *in:* Proc. Symp. Multiple-Use Manage. of Calif. Hardwood Resources (T. R. Plumb and N. H. Pillsbury, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest For. & Range Expt. Sta., Gen. Tech. Rep. PSW-100.
Abstract: Previous work in central California suggests that unsuccessful blue oak recruitment is more the result of mortality in the seedling and sapling stages rather than during germination and seedling emergence. Acorns were planted at two northern California sites to investigate the influence of yearly variation in rainfall, oak canopy, and cold storage on seedling emergence. Emergence was not affected by cold storage. Emergence was greater with below average rainfall and under blue oak canopy. These results suggest that the reasons for unsuccessful blue oak recruitment varies within the distribution of the species.

3100. McClaran, Mitchel P., and James W. Bartolome. 1989. **Effect of *Quercus douglasii* (Fagaceae) on herbaceous understory along a rainfall gradient.** Madrono 36(3):141-153.
Abstract: Variation in effect of approximately 50% *Quercus douglasii* (blue oak) cover on herbaceous understory biomass and composition was studied along a rainfall gradient between 5 sites. Biomass and composition were compared between understory and adjacent open grassland at each site to evaluate changes in canopy effect along the gradient. Biomass was measured at the time of greatest standing biomass (peak) in 1986 and 1987. Composition was measured at peak 1986. Annual rainfall was above average in 1985-86, and below average in 1986-87. In both years peak biomass was greater in grassland than understory at sites with >50 cm/yr average rainfall, and no difference was apparent at sites with <50 cm/yr rainfall. Variation in species composition between grassland and understory was independent of rainfall gradient. Differences in individual species presence and abundance between grassland and understory were found at all sites. We conclude that variation in canopy effect on biomass resulted from changes in relative production between understory and open grassland, not from differences in relative composition.

Natural resources specialist Robert Schmidt examines blue oak in conjunction with a field trial of stump sprouting success, 1989

3101. McCreary, Douglas D. 1989. **Stump sprouting – a regeneration alternative.** *In:* Proc. Hardwood Workgroup (R. B. Standiford and H. H. Kerner, eds.), Div. Agric. & Nat. Resour., Univ. Calif. Yuba City and Browns Valley, CA, Oct. 24-25. 6 pp.
Abstract: Several recent inventories of California oaks have indicated that blue oaks (*Quercus douglasii*) are not regenerating well in portions of the state. Efforts to artificially regenerate blue oaks by planting acorns or seedlings have revealed numerous obstacles to successful establishment. An alternative regeneration approach in stands of numerous trees is to incorporate a system of partial harvesting, with sprouting from cut stumps as a means of establishing new trees. This possibility was studied with a variety of harvesting procedures at five locations throughout the state, including Hopland. The results indicate that stump sprouting is a promising alternative for regenerating blue oaks in dense stands. To maximize sprouting, stumps should be cut about at 3 feet and protected against browsing of livestock and deer. There is the risk, however, that tall stumps are most susceptible to decay. Long-term monitoring will evaluate this risk.

3102. McCreary, Douglas D., William D. Tietje, Robert H. Schmidt, Rob Gross, William H. Weitkamp, Robert L. Willoughby, and Fremont L. Bell. 1991. **Stump sprouting of blue oaks in California.** Pp. 64-69 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage. (R. B. Standiford, tech. coord.), Davis, CA. USDA For. Serv., Gen. Tech. Rep. PSW-126.
Abstract: A study was conducted at five sites in California to determine the sprouting response of blue oak (*Quercus douglasii*) to varying harvest dates, stump heights, and fencing treatments. First and second year results indicated that harvest date had relatively little influence on sprouting, while stump height had a great impact. Nearly twice as many 90-cm stumps sprouted as did ground-cut stumps. Site also had a large influence. The average percent of stumps with live sprouts after 2 years ranged from 76% at one site to 37% another, and average shoot length ranged from over 1 m to less than 40 cm. While fencing had relatively little effect on the percent of stumps that sprouted, it greatly reduced browsing injury and

increased sprout length. These results suggest that sprouting by blue oak will result in the reestablishment of many harvested trees, but that a number of factors can influence sprouting success.

3103. McGourty, Glenn, Bruce Wyatt, Rollie Meyer, Charles E. Vaughn, and Milton B. Jones. 1990. **Potential of spray dried rendered products as agricultural fertilizers. I. Nitrate uptake rates of spray dried organic fertilizers by turf type tall fescue.** Preliminary Report prepared for California Spray Dry Co., Mendocino Co. Coop. Extension, Ukiah, CA. 6 pp.
Abstract: Nitrate uptake by turf type tall fescue (*Festuca arundinacea*) of spray dried fish meal, blood meal, feather meal, ammonium nitrate, and a commercial organic lawn fertilizer (Ringer Turf Restore) was measured by tissue analysis. Plants were grown in the greenhouse at Hopland at 85°F and 100°F maximum daytime temperatures and sampled at 2-week intervals for 10 weeks. Cumulative nitrate uptake was not significantly different between fertilizer treatments. Ammonium nitrate was taken up quickly and in significantly greater amounts than the organic fertilizers. Cumulative dry matter yields were similar for all plants receiving fertilizer. At the end of 10 weeks, percent nitrogen was higher in the plants receiving organic fertilizer than in ones treated with ammonium nitrate.

3104. McGourty, Glenn, Larry Schwankl, Bruce Wyatt, and Rollie Meyer. 1990. **Potential of spray dried rendered products as agricultural fertilizers. II. Injecting spray dried fertilizers into low volume irrigation systems.** Preliminary Report prepared for California Spray Dry Co., Mendocino Co. Coop. Extension, Ukiah, CA. 6 pp.
Abstract: Spray dried blood meal and fish meal were successfully injected into a drip irrigation system using 6 different brands of drip emitters, and a microsprinkler system using 5 different types of microsprinklers. Neither system showed any apparent clogging after two injections of blood meal and two injections of fish meal at a 75 ppm total N rate. The blood meal left significant residue in the lines and was evident when caught following flushing. Both visual observations and chemical testing of water caught from the beginning, middle, and ends of the irrigation system during injection indicate that blood meal is not uniformly distributed during injection. Fish meal appeared to be more uniformly distributed with less residue in the lines. Spray dried materials could not be successfully injected into drip tape without causing significant clogging.

3105. McGourty, Glenn A. 1992. **Organic soil amendments and fertilizers.** Pp. 27-29 *in:* Report to UC Sustainable Agric. Res. & Educ. Program Rept. 21505, Div. Agric. & Nat. Res., Univ. Calif.
Abstract: Marine-derived organic materials are a relatively minor class of soil amendments and fertilizers, in terms of amounts used. Research and field experience indicate that these materials can improve soil structure, enhance soil microbial activity, and promote plant growth. Current costs for processing and distribution, however, limit their use on a very wide scale, particularly for medium-to-large scale farmers in California's inland valleys. Four of the most common materials (fish waste, fish emulsion, shellfish waste and kelp/seaweed) are described along with chitin, a relatively new product.

3106. Menke, John W., and Michael E. Fry. 1980. **Trends in oak utilization - fuelwood, mast production, animal use.** Pp. 297-305 *in:* Proc. Symp. Ecol., Manage. and Utilization of Calif. Oaks (T. R. Plumb, tech. coord.), Claremont, CA. USDA For. Serv., Gen. Tech. Rep. PSW-44.
Abstract: Oak harvest levels in California were shown to be increasing rapidly. The foods produced by oaks, including acorns, leaves, twigs, and lichens were monitored for 2 years in blue oak, California black oak, and interior live oak. Oaks were shown to produce quite variable mast crops, whereas crops of leaves, twigs and lichens were rather steady in quality. Analyses of deer rumen content showed that deer rely heavily on oak foods in spring, summer, and fall, especially using acorns, when available from July through October. Acorns were shown to be an important dietary supplement for sheep, allowing them to maintain their weight when supplemented at 20% level in the diet or more.

3107. Mercier, Julien, and Steven E. Lindow. 1996. **A method involving ice nucleation for the identification of microorganisms antagonistic to *Erwinia amylovora* on pear flowers.** Phytopathology 86:940-945.
Abstract: A method was developed for the rapid selection of antagonists capable of suppressing growth of *Erwinia amylovora* on pear flowers. The population size of *E. amylovora* on flowers pretreated with potential antagonists was estimated by a flower-freezing assay. *E. amylovora* harboring the *ice*C gene from *Pseudomonas syringae* on the stable plasmid pVSP61 expressed high levels of ice nucleation activity. The threshold freezing temperature of flowers colonized by the ice nucleation-active (Ice^+) strain of *E. amylovora* increased linearly with the logarithm of the population size of the pathogen. Bacterial and yeast stains were selected from the predominant microflora of pear flowers and tested for their ability to lower the threshold freezing temperature of flowers subsequently inoculated with the Ice^+ *E. amylovora* strain. For each antagonist, the proportion of 20 treated flowers that had frozen was evaluated when approximately 95% of the control (*E. amylovora* only) had frozen. Among 257 strains tested, 45 (4 yeasts and 41 bacteria) were capable of reducing freezing of inoculated flowers by 70% or more. The reduction in the proportion of pretreated flowers that froze relative to the control for a number of antagonists was correlated ($R^2 = 0.61$) with reduced *E. amylovora* population sizes. Over 50% of the antagonistic strains that reduced the proportion of frozen flowers by 50% or more during an initial screening conferred a similar reduction in the number of frozen flowers in a second test. Several strains were more antagonistic to *E. amylovora* in situ than *P. fluorescens* strains A506, which is used commercially for biological control of fire blight.

3108. Mercier, Julien, and Steven E. Lindow. 2001. **Field performance of antagonistic bacteria identified in a novel laboratory assay for biological control of fire blight of pear.** Biological Control 22:66-71.
Abstract: A laboratory assay to identify antagonists of *Erwinia amylovora* on flowers was tested for its accuracy in predicting the performance of antagonists in controlling fire blight disease of pear trees. Bacterial strains isolated from pear flowers were evaluated in the laboratory for their ability to suppress growth of *E. amylovora* on flowers on cut branches. The growth of *E. amylovora* was assessed with a flower-freezing assay using a recombinant strain of the pathogen exhibiting an ice-nucleating phenotype. A number of antagonistic and nonantagonistic bacterial strains selected by this method were tested for their control of flower infection by *E. amylovora* on trees in the greenhouse and the field. There was a significant ($P \leq 0.01$) relationship between the ability of antagonists to suppress growth of *E. amylovora* in the flower-freezing assay and their ability to control fire blight on trees. Some of the strains identified conferred similar or better disease control that the biocontrol agent *Pseudomonas fluorescens* A506. None of the strains produced antibiotics inhibitory to *E. amylovora* on the culture media tested. All antagonistic and nonantagonistics strains survived well on pear flowers on trees and reached population sizes of approximately 10^5 to 10^6 cells/flowers 3 days after their application. The use of this flower-freezing assay has promise in the rapid identification of biocontrol agents of fire blight.

3109. Merenlender, Adina M. 1996. **Oak woodland symposium**

highlights issues, problems and solutions. Oaks 'n' Folks 11(1):4-5.
Abstract: Summarizes a symposium held in March 1996 in San Luis Obispo entitled "Oak Woodlands: Ecology, Management and Urban Interface Issues." The meeting included 90 papers addressing management issues and the biology of oak woodlands in California. Topics included were cattle grazing effects on water quality, tree stand growth modeling, habitat fragmentation, public policy and effects on private landowners, and revegetation techniques.


Robert J. Kelffer

Students plant trees as part of Adopt-A-Watershed program, Little Buck Pasture, Fall 1996

3110. Merenlender, Adina M., and Julia Crawford. 1998. **Vineyards in an oak landscape: exploring the physical, biological, and social benefits of maintaining and restoring native vegetation in and around the vineyard.** Publ. 21577, Div. Agric. & Nat. Resour., Univ. Calif. 15 pp.
Abstract: This publication provides guidance for development of vineyards in California's oak hardwood habitats in a manner so as to minimize impacts to important natural resources. The history of the wine grape industry's development of vineyards in oak woodlands is briefly described, along with the resulting habitat fragmentation that affects native plant and animal communities. Topics discussed include biodiversity, protection of oak trees, vine disease and the role of native vegetation (including Pierce's disease and oak root fungus), best management practices for vineyard development, and economic incentives. A vineyard development checklist and a list of useful references are included.

3111. Merenlender, Adina M., Kerry L. Heise, James W. Bartolome, and Barbara H. Allen-Diaz. 2001. **Monitoring shows vegetation change at multiple scales.** Calif. Agric. 55(6):42-46.
Abstract: Several historical data sets from the Hopland Research and Extension Center provide valuable information on vegetation dynamics at multiple spatial and temporal scales. An early botanical survey by Harold Heady and Al Murphy provides a baseline for examining landscape-level changes in species richness and distribution over 50 years. We conducted a floristic survey between 1995 and 1999 and found gains and losses of native and non-native species abundance across the field station. We did not relocate 43 species from the original survey, but we encountered 53 newly appearing species. Much of the species loss was attributed to vegetative conversion or displacement by invasive species. Over half the species that could not be relocated occurred initially in chaparral or wetland habitats. This can be partially explained by range improvement experiments in the 1960s and 1970s that converted some of the chaparral collection sites to grassland. In addition, some of the wetland collection sites are now dominated by pennyroyal (*Mentha pulegium*), an invasive non-native plant that was uncommon when first collected in 1969. Of the 53 "new" species found, about half were from wetland habitats. Of these, two-third were natives. "New" species found in grassland and xeric woodland habitats also consisted of native and non-native species; in contrast, only native species were found in rock outcrops, mesic hardwood forest, and chaparral. On two sites where sheep were removed in 1956, permanent transects provide valuable information about plant community responses to protection from livestock grazing; in the oak understory, native perennial blue wildrye increased steadily, while in grasslands native purple needlegrass was less abundant after 43 years. On a cleared watershed, originally diverse in hardwood species, we found that only interior live oak and coast live oak were significantly reestablished after 30 years. We have taken advantage of long-term monitoring studies at different spatial scales to show that both the herbaceous layer and the hardwood forests have changed over the past 50 years and are likely to continue to do so. To answer many of the questions raised by this and similar studies, it is essential to support research centers such at HREC. Preservation and maintenance of historic data sets provide essential information for ecological monitoring, a critical component of adaptive management.

3112. Murphy, Alfred H., and David Turner. 1959. **A study on the germination of medusahead seed.** Calif. State Dept. of Agric. Bull. 48(1):6-10.
Abstract: Medusahead represents a serious weed pest on California's rangelands and early recognition of this grass will tend to aid control. Burning in the dry stage offers an economical method of control. The fire destroys the seed of this annual plant thus diminishing the number of plants forming the next growing season. Germination tests indicate approximately a 90-day period of delayed germination after seed maturity. Seeds showing signs of scorching or having the awn burned off, in most cases, did not germinate. Seeds from soils in burned areas germinated greater where the burn was poor but showed no germination in a good burn.

3113. Murphy, Alfred H., and Harold F. Heady. 1983. **Vascular plants of the Hopland Field Station, Mendocino County, California.** Wasmann J. Biol. 41(1-2):53-96.
Abstract: Based on herbarium collections since 1951, this paper represents a checklist of the 600 species of vascular plants known to occur on the Hopland Field Station.

3114. Opperman, Jeff J., and Adina M. Merenlender. 2000. **Deer herbivory as an ecological constraint to restoration of degraded riparian corridors.** Restoration Ecol. 8(1):41-47.
Abstract: Ungulate herbivory can impact riparian vegetation in several ways, such as by reducing vigor or reproductive output of mature plants, and through increased mortality of seedlings and saplings. Much work has focused on the effects of livestock grazing within riparian corridors, while few studies have addressed the influence of native ungulate herbivory on riparian vegetation. This study investigated the effect of deer herbivory on riparian vegetation. This study investigated the effect of deer herbivory on riparian regeneration along 3 streams with degraded riparian corridors in Mendocino County, California. We utilized existing stream restoration efforts by private landowners and natural resource agencies to compare 6 deer exclosures with 6 upstream control plots. Livestock were excluded from both exclosure and control plots. Three of the deer exclosures had been in place for 15 years, one for 6

years, and two for 4 years. The abundance and size distribution of woody riparian plant species such as *Salix exigua, S. laevigata, S. lasiolepis, Alnus rhombifolia,* and *Fraxinus latifolia* were quantified for each exclosure and control plot. The mean density of saplings in deer exclosures was $0.49 + 0.15/m^2$, while the mean density of saplings in control plots was $0.05 + 0.02/m^2$. Within exclosures, 35% of saplings were less than 1 m and 65% were greater than 1 m; within control plots, 97% of saplings were less than 1 m in height. The fact that little regeneration had occurred in control plots suggests that deer herbivory can substantially reduce the rate of recovery of woody riparian species within degraded riparian corridors. Exclusionary fencing has demonstrated promising results for riparian restoration in a region in a region with intense deer herbivory.

3115. Phillips, Donald A., D. Michael Center, and Milton B. Jones. 1983. **Nitrogen turnover and assimilation during regrowth in *Trifolium subterraneum* and *Bromus mollis*.** Plant Physiol. 71:472-476.

Abstract: Subterranean clover (*Trifolium subterraneum*) and soft chess grass (*Bromus mollis*) were grown in monocultures with $^{15}NH_4Cl$ added to the soil to study nitrogen movement during regrowth following shoot removal. Four clipping treatments were imposed. Essentially all available ^{15}N was assimilated from the soil prior to the first shoot harvest. Measurements of total reduced nitrogen and ^{15}N contained within that nitrogen fraction in roots, crowns, and shoots at each harvest showed large, significant ($P < 0.001$) declines in excess N of crowns and roots in both species between the first and fourth harvests. There was no significant decline in total reduced nitrogen in the same organs over that period. Similar responses were evident in plants defoliated 3 times. The simplest interpretation of these data is that reduced nitrogen compounds turn over in plant roots and crown during shoot regrowth. Calculations for grass and clover plants clipped 4 times during the growing season indicated that 100% to 143% of the nitrogen present in crowns and roots turned over between the first and fourth shoot harvest in both species, assuming nitrogen in those organs was replaced with nitrogen containing the lowest available concentration of ^{15}N. If other potential sources of nitrogen were used for the calculations, it was necessary to postulate that larger amounts of total nitrogen flowed through the crown and root to produce the measured dilution of ^{15}N compounds. These data provide the first quantitative estimates of the amount of internal nitrogen used by plants, in addition to soil nitrogen or N_2, to regenerate shoots after defoliation.

Tracy Borland

HFS technician Brown San Diego and UC Davis agronomist Milton Jones at lysimeter, Spring 1976

3116. Phillips, Donald A., Milton B. Jones, D. Michael Center, and Charles E. Vaughn. 1983. **Estimating symbiotic nitrogen fixation by *Trifolium subterraneum* during regrowth.** Agron. J. 75:736-741.

Abstract: Two complementary experiments were conducted to determine whether symbiotic N_2 fixation could be estimated by applying ^{15}N technologies to *Trifolium subterraneum* organs that would remain after various grazing treatments. Both experiments analyzed monocultures and 50-50 mixtures of *T. subterraneum* and *Bromus mollis* planted at 2000 seeds/m^2 in ^{15}N-supplemented Laughlin loam, a member of the fine-loamy, mixed, mesic family of Ultic Haploxerolls. In one study, lysimeters were monitored through two growing seasons, while plant shoots were clipped once or 3 times during each growing season. In the other study, plants were grown in unleached pots under glasshouse conditions with various clipping treatments. Symbiotic N_2 fixation was estimated by the ^{15}N-dilution method and compared with the value determined from a total N-difference method that included leached N changes in the case of lysimeters. Clipping treatments had similar effects on both estimates of N_2 fixation in clover monocultures when shoot ^{15}N concentrations at the final harvest were used for the ^{15}N-dilution calculations. Shoot ^{15}N values also produced estimates similar to the N-difference method in clover-grass mixtures harvested only at the end of the season, but such ^{15}N-dilution calculations consistently underestimated N_2 fixation relative to the N-difference method for clover-grass mixtures clipped more than once. Using root or crown ^{15}N concentrations to estimate N_2 fixation produced lower values than the N-difference method in all clipping regimes and species compositions. A major difficulty in using either the ^{15}N-dilution technique or the N-difference method to estimate N_2 fixation in pastoral systems is that a measure of total reduced N harvested in the legume is required. This requirement can be met in clipping trials but not in continuous grazing studies. Efforts to calculate N_2-derived N in forage from ^{15}N concentration in shoots, crowns or roots remaining after previous clippings and reduced N in herbage of unclipped plants, a realistic technique for grazing studies, were inaccurate relative to the N-difference method in this study. Thus, one must conclude that although ^{15}N technologies can be used to estimate N_2 fixation with the same relative accuracy as the N-difference method in unclipped plants, neither technique can be applied with certainty when undetermined amounts of forage are removed by animals.

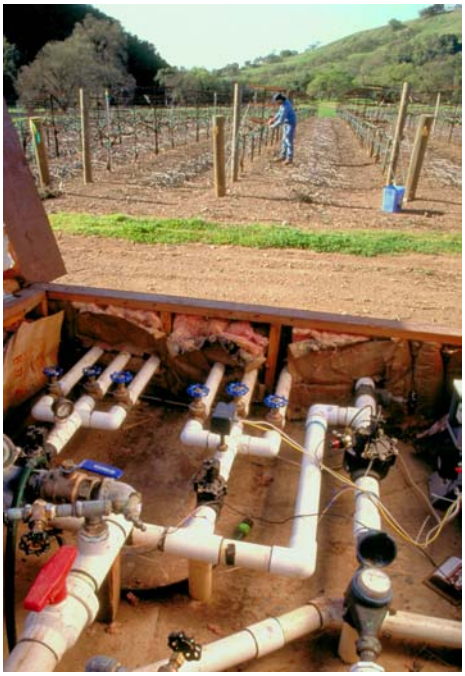
3117. Phillips, Donald A., Milton B. Jones, and K. W. Foster. 1983. **Advantages of the isotope dilution technique for field measurement of dinitrogen fixation (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 149.

***Abstract*:** Five years of field data from rangeland environments show that the isotope dilution technique detects differences in symbiotic nitrogen fixation by clover associated with treatments such as altered plant densities, clipping, and S or P fertilization. Such data represent qualitative estimates of nitrogen fixation with numerical values and limitations similar to those associated with the classical N-difference method. Data obtained by applying the isotope dilution method to 600 genotypes from 4 species of field-grown grain legumes show apparent genotypic variation in the capacity of nodulated plants to use soil N and dinitrogen. Identifying the basis of such differences may permit the development of plants that simultaneously optimize the use of soil N and dinitrogen, a result which could not be obtained with the N-difference or acetylene reduction methods.

3118. Phillips, Donald A., Milton B. Jones, and Ken W. Foster. 1986. **Ch. 2. Advantages of the nitrogen-15 dilution technique for field measurements of symbiotic dinitrogen fixation in legumes.** Pp. 11-21 *in:* E. A. Paul (ed.), Field Measurement of Dinitrogen Fixation and Denitrification, Spec. Pub. No. 18, Soil Sci. Soc. of America, Madison, WI.

Abstract: The ^{15}N-dilution technique for assessing N_2 fixation in

field environments has at least three important advantages: 1) its compatibility with normal agronomic measurements, 2) its capacity to integrate N_2 fixation over time with a single sampling, and 3) its capacity to estimate both soil N utilization and N_2 fixation in a single sample. A major problem with the ^{15}N-dilution assay is the selection of a suitable reference crop required to produce quantitatively accurate estimates of the ^{15}N content of soil or fertilizer-derived N. Agronomists are concerned primarily with treatment effects on N_2 fixation. Many reference crops that provide a baseline estimate of soil N use are available. By recognizing that a particular reference crop provides a qualitative estimate of N_2 fixation and soil N utilization, one can determine whether specific treatments increase or decrease N_2 fixation. At this time, we believe that qualitative answers to these questions will produce significant agronomic improvements.


Jack Kelly Clark

Irrigation system for irrigation trial in Cabernet vineyard, headquarters, April 1996

3119. Prichard, Terry L., and Rhonda J. Smith. 1997. **Modification of wine characteristics through irrigation management.** Interim Report to American Vineyard Foundation, Mar. 1, Univ. Calif. Davis. 4 pp.
Abstract: Fruit weights of experimental Cabernet Sauvignon vines at Hopland R & E Center were measured within plots for the purpose of assessing plot variability. Results indicated the average plot yield comes from a normal distribution with 90% level of confidence. Pre-treatment yields ranged from 13.5 to 15.9 lbs/vine. No significant differences were found among plots, assignment to treatments, or reps. Irrigation treatments will be imposed during the 1997 growing season as specific xylem (leaf) water potential thresholds.

3120. Prichard, Terry L., and Rhonda J. Smith. 1998. **Modification of wine characteristics through irrigation management.** Report to American Vineyard Foundation, June 1998, Univ. Calif. Davis. 10 pp.
Abstract: A study to evaluate effects of vine water management on winegrapes and wine quality began at Hopland R & E Center in 1997, utilizing an experimental 2-acre Cabernet Sauvignon vineyard in the headquarters area. This study utilizes measurements of xylem (leaf) water potential (XWP) as a trigger to determine when to begin irrigating. After a threshold XWP was reached, water was supplied at a fraction of full vine water use. The timing and quantity of applied water will impose various vine water deficits as treatments, with subsequent evaluation of must and wine characteristics. The experimental Cabernet Sauvignon vineyard is adjacent to the Nutrition Barn at the Hopland R & E Center. Yield, pruning weights, and crop/pruning ratios were measured/calculated finding no significant differences in yield. Yields averaged 21.4 lbs/vine with pruning weights at 7.7 lbs/vine and crop ratio of 3.4. Significant differences in berry weights were found with Treatments 1 and 6, which differed as a group from other treatments. Since all treatments were harvested at similar °Brix level, juice differences were confined to pH and titratable acidity. Titratable acidity (TA) was significantly higher in the full water treatment, which also had less measured sunlight at the fruiting level than all other treatments. It is likely that the increase in TA is a result of increased malic acid concentration. This is the first year of imposed treatments. The measured differences and similarities in treatments are in line with expectations in relation to yield and juice parameters. The approach of using leaf water potential as a trigger for irrigation and to use proportions of full water evapotranspiration (ET) to schedule irrigation timings and volume has been found to be simple and straightforward, indicating promise as an effective method of irrigation scheduling taking into account quality and yield parameters.

3121. Prichard, Terry L., Rhonda J. Smith, and Erica Lundquist. 1999. **Development of irrigation management strategies to improve fruit quality.** Report to American Vineyard Foundation, June 1999, Univ. Calif. Davis. 12 pp.
Abstract: At the experimental Cabernet Sauvignon vineyard at Hopland, the late spring rains in 1998 delayed the achievement of threshold leaf water potentials and therefore irrigation treatment initiation when compared to 1997. This delay may have reduced potential differences in vine canopy growth. For example, there were smaller differences among treatments in light measured at the fruit level in the canopy in 1998 as compared to 1997, and there were relatively few differences in shoot growth among treatments (measured only in 1998). In 1998, leaf water potentials reached lower levels than in 1997. A mild rain-filled spring provided for a large amount of vegetative growth. Spring was followed by a rapid move to greater than normal temperatures, which coincided with a low soil moisture reservoir. The vines then exhibited a leaf water potential in 1998 that was higher and less controlled by irrigation than in 1997. Yields were significantly different among treatments varying from an average of 19.1 to 24.7 lbs/vine (6.9 - 9.0 tons/acre). The full water treatment (T1) resulted in the highest yield, due to a higher individual berry weight; the fruit load (berries/vine) was not different among treatments. There were no significant treatment differences in juice pH or titratable acidity (TA). The more well-watered treatments, T1 (full water), T2, and T4 (both 60% of full water) had higher malate levels and lower potassium levels than did the treatments receiving lower water applications. The results thus far indicate the approach of using leaf water potential as a trigger to begin irrigation, and to use portions of full water evapotranspiration (ET) to schedule subsequent application volumes, is an effective method of irrigation scheduling that takes into account quality and yield parameters.

3122. Prichard, Terry L., Rhonda J. Smith, and Erica Lundquist. 2000. **Development of irrigation management strategies to improve fruit quality.** Report to American Vineyard Foundation, March 2000, Univ. Calif. Davis. 12 pp.
Abstract: This project at an experimental Cabernet Sauvignon vineyard at Hopland R & E Center utilizes midday leaf water potential (LWP) as a trigger to determine when to begin supplying irrigation water. After a threshold LWP has triggered the start of the irrigation season, water is supplied, depending on treatment, at a

fraction of full vine water use. It is our goal to use water management, as defined as the timing and quantity of applied water, to impose vine water deficits as a means of producing desirable must and wine characteristics. A dry spring and cool summer characterized the 1999 season. Due to lack of spring rain, irrigation was started approximately one month earlier in the full water treatment than in 1998. Leaf water deficits took 2 months to develop, as compared to 5 weeks in 1998. Canopy growth was somewhat reduced in 1999 as compared to 1998. Final shoot lengths were shorter in all treatments, and fruit level light conditions were higher in 1999 than in 1998. Yields varied significantly among the treatments with the full water treatment resulting in the highest yield, the intermediate water treatments, 60% or 35/60% full ET, resulting in intermediate yields, and the 35% full ET treatments resulting in the lowest yields. Yields averaged from 18.5 to 29.3 lbs/vine (6.7 - 10.6 tons/acre). Yields were higher in the full, 60% and 35/60% full ET treatments relative to 1998, and were the same or lower for the 35% ET treatments. Malate and titratable acidity were highest in the full water treatment (T1), intermediate in T2 and T4, receiving 60% of full ET, and lowest in the 35 and 35/60% treatments (T3, T5, T6). Significant differences among the treatments in pH, Brix, and potassium also occurred, however these differences did not appear to follow irrigation levels.

A. H. Murphy

HFS foreman Fran Lile sets up propane cannon for demonstration of bird protection in vineyards, Grape Field Day, September 1969

3123. Prichard, Terry L., Rhonda J. Smith, and Erica Lundquist. 1999. **Development of irrigation management strategies to improve fruit quality.** Report to American Vineyard Foundation, March 2001, Univ. Calif. Davis. 12 pp.

Abstract: This study is being conducted in an experimental Cabernet Sauvignon vineyard at the Hopland R & E Center. Its purpose is to evaluate an approach to vine water management appropriate to cooler growing regions that will provide growers the tools they need to know when to begin to irrigate, when to schedule subsequent irrigations, and how much water to apply each time they irrigate. This research project utilizes measurements of midday leaf water potential (LWP) as a threshold to determine when to begin supplying irrigation water. After a threshold LWP has triggered the start of the irrigation season, water is supplied at a fraction of full vine water use; this fraction is called the regulated deficit irrigation (RDI) percentage. Threshold leaf water potentials were reached, and irrigation began on August 1st for T4, T5, and T6 (-12 bar thresholds) and on August 22nd for T3 and September 3rd for T2 (both -14 thresholds). Irrigation to replace a treatment-determined portion of full water use was conducted weekly in each deficit treatment. When irrigation began at -12 bars, the 60% RDI (T4) maintained a rather constant water status as the season progressed ending near harvest at -11.8 bars. The same threshold in the 35% RDI treatment resulted in a progressively more severe water status ending at -14.1 bars. The RDI 35% with a -14 bar threshold lost ground over time to end the season at -15.2 bars. After irrigation began with a -14 bar threshold, the 60% RDI maintained a rather constant water status as the season progressed ending at -13.5 bars. After the RDI percentage was increased in T6, the level of water stress was reduced by more than 2.0 bars over a 21-day period when compared to Treatment 5. The effect of the 60% RDI on both -12 and -14 threshold treatments was to maintain the level of water stress of when the irrigation started; near -12 for the -12 threshold and near -14 for -14 bar threshold. The effect of the 35% RDI was to cause increasingly more water stress as harvest approached. Canopy growth was similar to that in 1999. Final shoot lengths were between 122 and 152 cm with the longest being the full water treatment (T1). Fruit level PAR was also similar to 1999 with differences found between the least and most water stressed treatments. Yields were not significantly different among treatments, with the full water treatment (T1) averaging 30.8 lb/vine (11.2 tons/acre) and the lowest-yielding treatment (T3-14/35) averaging 21.3 lbs/vine (7.7 tons/acre). Malate was highest in T1 over all other treatments. A significant relationship exists between treatment consumptive water use (ET) and malate levels in the juice at the 99% confidence level. There were significant differences in pH and potassium levels among the treatments as well, however these differences did not seem to follow water use volumes.

3124. Radosevich, Steven R., S. G. Conard, and D. R. Adams. 1977. **Regrowth responses of chamise following fire.** Pp. 378-382 *in:* Proc. Symp. Environ. Consequences of Fire and Fuel Manage. in Mediterranean Ecosystems (H. A. Mooney and C. E. Conrad, tech. coords.), Palo Alto, CA. USDA For. Serv., Gen. Tech. Rep. WO-3.

Abstract: Shoot growth responses, plant water relationships, and photosynthetic ability of unburned chamise and chamise scrub regrowing following several controlled burns was investigated. Nutritional, hormonal, and environmental control of chamise shoot growth was also studied. Data from field studies indicate an inverse relationship between xylem sap tension and both shoot growth and production. The extrapolation of *in vitro* studies to a field situation suggests that regulation of chamise shoot growth by water stress may be physiologically mediated by a direct reduction of carbohydrate or its availability to the shoot apex, a decrease in cytokinin at the apex, or an increase in inhibitor level in the shoot tips.

3125. Rice, Kevin J. 1985. **Responses of *Erodium* to varying microsites: the role of germination cueing.** Ecology 66(5):1651-1657.

Abstract: I examined the role of germination cueing in the dynamics of *Erodium botrys* and *E. brachycarpum* populations exposed to localized, spatial variation within California annual grasslands. In laboratory trials, germination rates of both species increased significantly in seeds previously exposed to fluctuating temperatures (25-45°C) during dry storage. Temperature fluctuations per se were more important than temperature maxima for increasing germination rates. Light conditions during germination had no significant effect on germination rates. Field trials were also conducted. Summer soil temperature regimes were characterized for 3 germination microsites of *Erodium*: 1) under dense litter of annual grasses, 2) in bare soil, and 3) under mounds created by burrowing pocket gophers. Diurnal fluctuations in soil surface temperature were 17-51°C on bare soil, 20-41° under litter, and 18-35° under gopher mounds. Summer field manipulation examined the rates of release from seed dormancy for buried seeds; both species showed a strong positive relationship between germination rates and the mean diurnal range of temperatures for each microsite. To examine whether seed germination rates were accurate predictors of the suitability of a site for *Erodium* colonization, germinated seeds of both species were

introduced into each microsite type at the start of each growing season. Emergence rates and survival were significantly reduced in mound microsites; seed output per plant was lower in litter microsites. There was a strong positive relationship between *Erodium* colonization success, as measured by net reproductive rate, and the mean summer diurnal range of soil temperatures. The accuracy of cueing response in predicting site suitability was reduced with drought or heavy grazing. The results overall suggest significant adaptive value for germination cueing in both *Erodium* species.

3126. Rice, Kevin J., and John W. Menke. 1985. **Competitive reversals and environment-dependent resources partitioning in *Erodium*.** Oecologia 67:430-434.
***Abstract*:** Effects of drought and varying plant density on the competitive coexistence of two winter annual *Erodium* species were studied using multiple regression analysis. Significant indications of resource partitioning were detected for interspecific mixtures under spring drought. Competitive superiority was also environment dependent with *E. botrys* dominating with drought in autumn, while *E. brachycarpum* dominated with drought in spring. The results suggest that competitive coexistence in *Erodium* is promoted by processes both equilibrial (e.g. resource partitioning) and nonequilibrial (e.g. competitive reversals).

3127. Rice, Kevin J. 1987. **Evidence for the retention of genetic variation in *Erodium* seed dormancy by variable rainfall.** Oecologia 72:589-596.
Abstract: The periodic occurrence of summer/early autumn precipitation in the California annual grassland can result in formation of early and late emerging cohorts of *Erodium botrys* and *E. brachycarpum.* The occurrence of early rainfall and the timing of such rainfall are highly variable from year to year. A series of field watering experiments in 1980-81 were used to simulate early emergence conditions that would result from significant rainfall (1 cm) occurring in mid-July, late August, and mid-September. Net reproduction was used to estimate fitness differentials between *Erodium* cohorts emerging in response to a watering treatment (early emerging cohorts) and *Erodium* cohorts emerging with the onset of winter rains in mid-October (late emerging cohorts). Survival was lower and gross reproduction was higher among early emerging cohorts than late emerging cohorts. For both species, net reproduction of the early cohort was lower than that of the late cohort under the July watering treatment and higher than that of the late cohort under the August watering treatment. Early cohorts formed in response to rainfall in mid-September 1982 were also compared demographically to later cohorts emerging in October. Compared to late cohorts, net reproduction, gross reproduction, and survival were higher for the early cohorts. Common garden experiments indicate the differences in the duration of seed dormancy between the progenies of early and late emerging plants reflect a significant genetic component. Progeny produced by early cohorts of *E. brachycarpum* from all 3 watering treatments possessed more extended seed dormancy than progeny of late cohorts. In *E. botrys*, progeny from early cohorts emerging in response to the July watering treatment were also more dormant than late progeny. In contrast, early cohorts of *E. botrys* emerging in response to September watering treatment produced seed less dormant than seed produced by late cohorts. When combined with demographic data, indicating that fitness differentials between early and late cohorts varied with changes in the date of early emergence, genetic results suggest that year to year variation in early rainfall may act to retain genetic variation in the duration of seed dormancy.

3128. Rice, Kevin J. 1987. **Interaction of disturbance patch size and herbivory in *Erodium* colonization.** Ecology 68(4):1113-1115.
Abstract: This study examined the importance of small-mammal herbivory in preventing *Erodium* colonization of soil disturbances in grasslands protected from sheep grazing, and the interaction of disturbance patch size and small-mammal (California vole, *Microtus californicus*) grazing intensity on *Erodium* colonization. *Erodium* survivorship was much higher in disturbed plots protected from small-mammal herbivory. There was also a patch-size effect, as large-patch plots had higher *Erodium* survival rates when compared to small-patch plots. Variation in net reproduction across treatments paralleled the survivorship data. High growth rates in protected *Erodium* populations suggests that small-mammal herbivory is an important factor in preventing *Erodium* from colonizing soil disturbances in grasslands ungrazed by domestic herbivores.

3129. Rice, Kevin J., Doria R. Gordon, Jeanine L. Hardison, and Jeffrey M. Welker. 1991. **Intraspecific phenotypic variation and ecological genetics of blue oak (*Quercus douglasii*).** Pp. 59-63 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage. (R. B. Standiford, tech. coord.), Davis, CA. USDA For. Serv., Gen. Tech. Rep. PSW-126.
Abstract: We examined potential variation in water use efficiency (WUE) in both mature trees and seedlings of blue oak by measuring the carbon isotope composition of plant tissue collected from populations arrayed along a latitudinal rainfall gradient. We also conducted common garden studies to determine the potential genetic basis for phenotypic variation in seedling WUE, growth, and phenology. We planted acorns from both xeric and mesic populations into herbaceous neighborhoods characterized by different rates of soil water depletion. Acorns from the mesic site were significantly smaller. While the probability of emergence increased with acorn size in the xeric population, there was no effect of acorn size on the emergence in the mesic population. Seedling WUE was influenced significantly by herbaceous neighborhood composition. Average leaf size and stem weight increased with acorn size in the mesic population. Differences among maternal families in the mesic population suggested significant within-population genetic variation for seedling traits. Further, leaf weight responded differently among families to variation in neighborhood composition, suggesting genetic variation for plasticity in leaf morphology.

3130. Rice, Kevin J., D. R. Gordon, J. L. Hardison, and J. M. Welker. 1993. **Phenotypic variation in seedlings of a "keystone" tree species (*Quercus douglasii*): the interactive effects of acorn source and competitive environment.** Oecologia 96:537-547.
Abstract: Blue oak (*Quercus douglasii*) is a deciduous tree species endemic to California that currently exhibits poor seedling survival to sapling age classes. We used common garden techniques to examine how genetic variation at regional and local scales affected phenotypic expression in traits affecting oak seedling growth and survival. Between-population variation was examined for seedlings grown from acorns collected from a northern, mesic population and a southern, xeric population. Within-population variation was examined by comparing seedlings from different maternal families within the mesic population. Acorns were planted into neighborhoods of an annual dicot (*Erodium botrys*), an annual grass (*Bromus diandrus*), and a perennial bunchgrass (*Nassella pulchra*). By varying the species composition of herbaceous neighborhoods into which acorns were planted, the interactive effects of competition and acorn germplasm source on phenotypic expression could also be examined. Potential maternal effects, expressed as variation in acorn size, were assessed by weighing each acorn before planting. Probability of seedling emergence increased significantly with acorn size in the xeric population but not in the mesic population. Similarly, the effect of acorn size on seedling leaf area, stem weight, and root weight was also population-dependant. At a within-population level, acorn size effects on seedling traits varied significantly among maternal families. In addition to acorn size effects, rates of oak seedling emergence were also dependent on an

interaction of population source and competitive environment. Interactions between maternal family and competitive environment in the expression of seedling leaf characters suggest the possibility of genetic variation for plasticity in traits such as specific leaf area. Using carbon isotope discrimination as an index of relative water-use efficiency, higher water use efficiency was indicated for oak seedlings grown in the annual plant neighborhood. This trend may represent an adaptive plastic response because, compared to the bunchgrass neighborhood, soil water depletion was more rapid within annual plant neighborhoods.

3131. Rice, Kevin J. 1994. **The role of plant population biology and ecophysiology in the conservation and management of blue oak savanna in California (Poster presentation).** *In:* Proc. Symp. Future of Tropical Savannas: An Australian Perspective, Townsville, Australia. CSIRO/James Cook University, Jul. 17-24.
Abstract: The blue oak (*Quercus douglasii*) savanna is a hardwood range ecosystem unique to California. Our research, stimulated by a potential lack of regeneration, encompasses both ecological and evolutionary constraints on the survival and growth of blue oak seedlings. We focus on the critical transition period between seedling and sapling, with the goal of developing a management scheme that will significantly improve recruitment rates. A general conclusion from a series of studies is that the rate of soil water depletion in spring and early summer is a critical determinant of negative effects of a competitor on blue oak seedlings. Although earlier work suggested that soil water depletion was typically more rapid near introduced annual species, more recent results indicate that mature stands of native perennial bunchgrasses can extract soil water at a rate than exceeds that of the exotic annuals. It was found that the relative importance of acorn source (between-population variation) and competitive environment in affecting seedling response was trait-dependent. Seedling water-use efficiency and seedling leaf traits exhibited plastic responses to environmental variation; the magnitude and direction of phenotypic responses varied among maternal families. Significant genetic variability for plasticity may exist within populations. Acorn size often is related to survival and growth of seedlings, but the strength of this positive correlation varies among populations. Differences in acorn traits are found among maternal families within a single population, and such variation is quite constant from one year to the next, suggesting a potential genetic component. We found that there is significant variation among trees in acorn maturity at the time of acorn drop; trees with greater water stress appear to release acorns at a more immature stage. Such acorns grow more slowly than more mature fruit. A long term reciprocal transplant study has been initiated at 4 locations to assess local adaptation. Significant differences among germplasm sources in both survival and growth were apparent after 2 years; the relative population of the local population at a site appears to be site-dependent, indicating both significant adaptation and also relative mal-adaptation.

3132. Rice, Kevin J., James H. Richards, and Steven L. Matzner. 1997. **Patterns and processes of adaptation in blue oak seedlings.** Pp. 109-115 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: Reciprocal transplant studies examined the contribution of genetic differentiation and phenotypic plasticity to intraspecific variation in blue oak (*Quercus douglasii*) seedling survival and growth. A nested, mixed model design partitioned seedling survival and growth responses into between-population effects, within-population (among family) effects, and environmental effects. Significant between-population differences in seedling survivorship and growth were observed at both sites. Interactions between population source and planting block suggest local scale adaptation. Differences among maternal families in survival and growth were significant. Phenotypic variation in seedling performance may be related to indices of acorn quality such as embryo dry weight.

3133. Rubtzoff, Peter, and Lawrence R. Heckard. 1975. **New distributional records for California flowering plants of aquatic and moist habitats.** Wasmann J. Biol. 33(1-2):89-106.
Abstract: This paper describes the following plants found at the Hopland Field Station: *Cypselea humifusa, Eleocharis radicans, Eleocharis acicularis* (slender spikerush), *Eragrostis hypnoides,* and *Glyceria borealis* (northern mannagrass). *C. humifusa*'s range was extended when identified near Hopland Field Station's Headquarters Lake. In Mendocino County, *E. radicans* is not uncommon, to judge from several collections in the Navarro River and Hopland region. At Hog Lake on the Hopland Field Station, colonies of *E. radicans* and *E. acicularis* occupy concentric, partly overlapping zones around the desiccating lake; *E. acicularis*, a plant more tolerant of dryer situations, extends farther away from the water margin than *E. radicans*. The only known sample of *E. hypnoides* in Mendocino County came from several collections on the Hopland Field Station. A noteworthy occurrence of *G. borealis* was made at the Hopland Field Station. This widely disjunct occurrence was discovered by Dr. Harold Heady and Alfred Murphy; they collected the species at several localities on the station. *G. borealis* occurs at the station below 1000 feet altitude; previously reported altitudinal ranges were 4000-7000 feet and 2750-7000 feet. The specimens were deposited at the Range Management Herbarium at University California, Berkeley, and the Hopland Field Station herbarium.

3134. Sakai, T., H. Maarse, R. E. Kepner, W. G. Jennings, and W. M. Longhurst. 1967. **Volatile components of Douglas fir needles.** Agric. and Food Chem. 15(6):1070-1072.
Abstract: Volatile components of Douglas fir (*Pseudotsuga menziesii*) isolated by steam distillation and ether extraction were separated by repetitive gas chromatography on dissimilar substrates, utilizing both packed and wide-bore capillary columns. Individual components were characterized by relative retentions on several columns, Kovats' indices, and infrared spectroscopy. Compounds identified include α-pinene, camphene, ß-pinene, 3-carene, myrcene, limonene, 2-hexenal, ethyl caproate, γ-terpinene, terpinolene, ethyl caprylate, citronellal, linalool, fenchyl alcohol, bornyl acetate, terpinen-4-ol, ß-caryophyllene, citronellyl acetate, α-terpineol, citronellol, geranyl acetate, and farnesyl acetate; *p*-cymene and farnesol were identified on the basis of relative retentions only. Infrared spectra were obtained for two additional terpene alcohols and an aromatic alcohol which could not be identified.

3135. Savelle, Glenn D. 1977. **Comparative structure and function in a California annual and native bunchgrass community.** Ph.D. Dissertation, Univ. Calif. Berkeley. 276 pp.
Abstract: A 27-month comparative study was conducted on the Hopland Field Station, of above- and below- ground vegetational structure and function within an annual grassland and a *Stipa pulchra* bunchgrass community. Both communities were naturally established under conditions of nearly identical climate, soil, topography, and potential organisms. Field measurements encompassed a year of normal rainfall, a drought year, and other years when the *Stipa* site was predominantly annual grassland. The study documented community reactions to natural environmental perturbations and to changes when one community replaced the other. Decomposition rates within the mulch and root compartments, spatial distribution of mulch, and temporal patterns of detritus transfer exerted profound influence on community productivity and energy flow. Decomposition rates varied significantly among seasons, sites, and plant materials, but the pattern of decomposition activity was similar for both communities and different from those reported in the literature for other grassland types. Overall rates were

70-100% higher on the annual site than on the perennial site. A 50-200% larger mulch and standing dead overburden existed at all times in the perennial community, resulting in an environment less favorable to microorganisms, in delayed phenological development, in reduced herbage production, and in a vertical distribution of detritus less suited for maximum decomposition activity than in the annual community. A distinct floristic structure developed as the *Stipa* community replaced the annual type: diversity decreased, dominance increased, and forbs, especially legumes, became relatively unimportant. Community differences also included dissimilar root distributions and depths of penetration. Total accumulated root biomass was higher on the perennial site but total soil organic matter was reduced by one-third. Functionally, the annual grassland had a higher growth rate throughout winter and early spring, but the total potential productive capacity was greater in the bunchgrass community. These results were probably due to a relatively high rate of *Stipa* growth for 4-6 weeks after the annuals were drying and the large co-dominant annual grass component of the perennial community, which permitted an effective horizontal distribution of leaves and use of light. Under moisture stress, production of biomass on the perennial site fell below that of the annual grassland, suggesting that bunchgrass stands on the central coast ranges would be less stable and more subject to annual fluctuations in net productivity. Conversely, root production showed greater stability on the perennial site. The caloric content of live plant materials differed significantly between species, morphological groups, sites, seasons, and years, while that of the mulch differed between seasons and years.

Harold Jones

Wildlife research associate Guy Connolly examines acorn trap, November 1966

3136. Schmidt, Robert H., and P. Tucker-Wolff. 1988. **Blue oak seedling research: why do small seedlings disappear?** Oaks 'n' Folks 3(1):1-2.
Abstract: The authors describe a study in which 80 naturally-occurring blue oak seedlings growing under mature oak trees were marked and observed through time. The study site excluded livestock, but seedlings were subject to browsing by deer, rodents, and insects. Seedlings were observed every 2 weeks from June 1987 through February 1988. Under the first tree, many of the 40 seedlings marked appeared to experience early dormancy from lack of moisture, while many of the 40 seedlings under the second tree suffered chewing, girdling, or clipping of the stems, mostly by grasshoppers. Subsequently, many of the seedlings appeared to recover from injuries; 29 of 32 seedlings that were girdled, stripped, or clipped were observed to put out new buds, while all of 38 seedling showing effects of drought also put out new buds by February 1988. These data indicate that blue oak seedlings are quite forgiving of injury, at least for one growing season. Concern remains that most if not all seedlings on rangelands, for whatever reasons, do not survive to reach maturity.

3137. Schmidt, Robert H. 1990. **Effect of controlled-release fertilizers on the survival and growth of out-planted blue and valley oak acorns.** Pp. 4.1 – 4.18 *in:* Selected Techniques for Restocking Hardwood Rangelands in Calif. with Native Oaks. Rep. of Integr. Hardwood Range Manage. Prog. to Calif. Dept. Forest. and Fire Protect.
Abstract: This project demonstrated that the effect of fertilization on planted blue oak and valley oak acorns may be slight, since no fertilizer treatment produced seedlings with a mean height larger than that of the control. Some fertilization practices may in fact inhibit seedling emergence and growth. Planting date has a more pronounced effect on both emergence and seedling height, with earlier planting favoring more emergence and taller seedlings.

3138. Schmidt, Robert H. 1991. **Dining on the oaks.** Outdoor Calif. 52(4):1-4.
***Abstract*:** This paper reviews the incredible array of insects and animals that affect oak regeneration. Animals consuming acorns and oak seedlings is not an unnatural act, they have done so for thousands of years. In fact, oaks have adapted to this predation pressure with a variety of defenses. However, the failure of natural regeneration to be of sufficient quality and quantity to maintain current stands of some species of oaks indicates that something has happened which upset the status quo. Perhaps there are more herbivores in the landscape now. The introduction of alien annual grasses and livestock, and the suppression of natural fire patterns has certainly aided this condition. In response, researchers and vegetative restorationists are devising a number of techniques to protect planted oaks while restoring, replacing, and rejuvenating oak woodlands.

3139. Schultz, Thomas H., Dale R. Black, T. Richard Mon, and Guy E. Connolly. 1976. **Vinegar weed volatile constituents.** Agric. and Food Chem. 24(4):862-865.
***Abstract*:** The essential oil from vinegar weed (*Trichostema lanceolatum*) was prepared from the leaves and stems by distillation and solvent extraction (yield 0.6%). The oil was analyzed by combined gas chromatography-mass spectrometry and GC retention time. Identified constituents (with rough quantitative indications) were terpinen-4-ol (55%), γ-terpinene (15%), α-terpinene (7.7%), terpinolene (3.2%), *p*-cymene (1.9%), ß-phellandrene (1.4%), α-pinene (1.3%), α-terpineol (1.3%), and caryophyllene (1.2%). Twelve other constituents also were identified in the aqueous phase of the distillate, and its abundance in the leaves and stems estimated to be about 0.2%.

3140. Schultz, Thomas H., Dale R. Black, T. Richard Mon, and Roy Teranishi. 1980. **Turkey mullein volatile constituents.** J. Agricultural and Food Chem. 28:1255-1258.
Abstract: Extracts of the volatiles from turkey mullein (*Eremocarpus setigerus*) were prepared from the leaves and stems by simultaneous steam distillation and extraction (SDE), both at atmospheric pressure (yield 0.057%) and at 100 torr (yield 0.005%). The extracts were analyzed by combined gas chromatography-mass spectrometry and GC retention matching. Identified constituents (with semiquantitative indications for the atmospheric-prepared extract) were β-pinene (21.5%), myrcene (21.3%), *trans*-ethyl cinnamate (12.7%), nonanal (4.2%), *trans*-2-methylbutyl cinnamate (3.7%), α-pinene (2.8%), *trans*-isobutyl cinnamate (2.7%), 2-methylbutyl hexanoate, (2.6%), *cis*-ethyl cinnamate (2.2%), limonene (1.6%), *trans*-butyl cinnamate (1.5%), and citronellol (1.0%). Many other constituents also were identified, at concentrations less than

1%, to make a total of 59.

3141. Schwankl, Lawrence J., and Glenn A. McGourty. 1992. **Organic fertilizers can be injected through low-volume irrigation systems.** Calif. Agric. 46(5):21-23.
Abstract: The practice of injecting organic fertilizers into low-volume irrigation systems is not widespread, partly because of concerns that the materials will clog emitters. This study looks at two spray-dried organic fertilizers (fish protein and poultry protein). Both were both shown to be injectable through microsprinkler, drip and drip-tape irrigation systems with minimal clogging. Both fertilizer products were also shown to be emitted uniformly along the 300-foot lateral lines tested.

3142. Spencer, K., J. R. Freney, and Milton B. Jones. 1984. **A preliminary testing of plant analysis procedures for the assessment of the sulfur status of oilseed rape.** Aust. J. Agric. Res. 35:163-175.
Abstract: The effects of sulfur and nitrogen supply on the distribution of sulfur in oilseed rape (*Brassica napus* cv. Oro) grown in a sulfur-deficient soil in a glasshouse were examined to provide basic information for the development of a diagnostic test for sulfur status. Even though the traditional diagnostic indices (total sulfur and sulfate concentration) were directly related to sulfur supply and exhibited wide ranges in values between deficient and non-deficient tissue, they suffered a number of drawbacks in the case of oilseed rape. The shape of the yield/composition relationship precludes the use of either total nitrogen:total sulfur ratio or the proportion of the total sulfur present as sulfate in very young plants as indices for predicting the adequacy of sulfur supply up to first seed set. However, either index looked promising at 59 days from sowing, especially if specific plant parts were selected for analysis. For diagnosis of the current sulfur status, the proportion of the total sulfur present as sulfate gave a good indication at each sampling date, and the critical value for the shoots was relatively stable with respect to age and nitrogen supply. Total nitrogen:total sulfur ratio was satisfactory as a diagnostic index for the 59-day-old plants only. Whilst the relationships established between the indices on one hand, and plant part, age, and nitrogen supply on the other, should also apply in the field environment, the magnitude of the critical ratios requires confirmation for practical application.


A. H. Murphy

County Supervisor Charles Barra (l) and Extension advisor Bruce Bearden (r) at Grape Field Day, Niderost Pasture, September 1969

3143. Stockwin, Will. 1996. **Med reds on trial: these grape varieties from overseas may prove successful even in poor soils.** Western Fruit Grower 116(1):22-23.
Abstract: Many winegrape varieties from the Rhone Valley, Spain, and Italy may be better suited to Mendocino County's dry heat than the commonly grown varietals which were developed in the more northerly areas of Bordeaux and Burgundy. The climate match for these less commonly grown grapes promises wines of surpassing character. Limited experience in the state suggests that these varieties must be limited in vigor and yield to produce grapes suitable for good wines. Some of the varieties produce medium-bodied wines which will require that winemakers will have to learn some different methods. The subtle character of the wines complement food well. To study this potential, a 10-year trial of 20 Rhone, Italian, and Spanish varieties was begun at the UC Hopland R & E Center.

3144. Swiecki, Tedmond J., Elizabeth A. Bernhardt, and Christiana Drake. 1997. **Factors affecting blue oak sapling recruitment.** Pp. 157-167 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: We used logistic regression to identify environmental and management history factors associated with blue oak (*Quercus douglasii*) sapling recruitment. Recent canopy gaps caused by natural mortality or clearing were positively associated with sapling recruitment. Plots with very high or low levels of tree canopy cover were less likely to have saplings than those with intermediate canopy cover levels. Across all locations, and within grazed locations, browsing intensity was negatively associated with sapling presence. Other factors significantly correlated with sapling recruitment include shrub presence, insolation, soil available water-holding capacity, fire, plot altitude, precipitation, and potential evapotranspiration.

3145. Swiecki, Tedmond J., Elizabeth A. Bernhardt, and Christiana Drake. 1997. **Stand-level status of blue oak sapling recruitment and regeneration.** Pp. 147-156 *in:* Proc. Symp. Oak Woodlands: Ecology, Management, and Urban Interface Issues (N. H. Pillsbury, J. Verner, and W. D. Tietje, tech. coords.), San Luis Obispo, CA. USDA For. Serv., Pac. Southwest Res. Sta., Gen. Tech. Rep. PSW-GTR-160.
Abstract: We assessed blue oak (*Quercus douglasii*) sapling recruitment and regeneration at 15 locations distributed throughout the range of blue oak. Overall, 15.3 percent of the 1,500 plots surveyed contained blue oak saplings. Four locations had moderate numbers of saplings, and the remaining locations had few to no saplings. Seedling-origin saplings were far more common than stump-sprout saplings. Most saplings were shorter than the browse line (1.4 m). At 13 of the 15 locations, sapling recruitment is inadequate to offset recent losses in blue oak density and canopy cover.

3146. Vasey, Michael C. 1980. **Natural hybridization between two evergreen black oaks in the north central coast ranges of California.** Pp. 30-35 *in:* Proc. Symp. Ecol., Manage. and Utilization of Calif. Oaks (T. R. Plumb, tech. coord.), Claremont, CA. USDA For. Serv., Gen. Tech. Rep. PSW-44.
***Abstract*:** Hybridization between coast and interior live oaks is recognized and appears to be concentrated in the northern portion of their overlapping ranges. A hybrid mix analysis of selected populations of these species along a 175 mile north/south gradient confirms this observation, and an examination of the fossil record suggests a reason for this pattern of concentration. After a long period of isolation, ancestors of these two oaks converged during the Middle Pliocene and dramatic oscillations of climate in California since that time provided ample opportunity for hybrid establishment particularly at their range extremes in the north central Coast Ranges. It is suggested that this study could be improved by incorporating *Quercus kelloggii* into a computerized hybrid analysis of all 3 species.

3147. Vaughn, Charles E. 1974. **Nondestructive acetylene reduction assays of intact nitrogen-fixing systems in soil.** M.S. Thesis, Univ. Calif. Davis. 52 pp.
Abstract: A method for short-duration acetylene reduction assays of nitrogen fixation by intact nitrogenase systems in soil was developed. Undisturbed cultures were grown in 2.4-liter polyethylene pots. The pots were sealed, the cultures exposed to an air-acetylene atmosphere, and assayed for ethylene production. No lag period was observed in the ethylene production rates of subclover plants (*Trifolium subterraneum*) if the gases were mixed during an incubation by pumping a syringe inserted through a rubber serum stopper fitted in the bottom of the pot. Acetylene saturated the nitrogenase systems of excised subclover nodules at a pC_2H_2 of 0.10 atm, but for ease of handling the standard assays were conducted at a pC_2H_2 of 0.05 atm. Ethylene production at saturating acetylene levels was calculated with the Michaelis-Menten equation. Diurnal variation in nitrogenase activity was large so a mean daily activity value was used in calculating daily ethylene production. Successive biweekly assays of 60-minute duration were conducted on 7 species of annual clovers during complete growth and maturation cycles. There was a significant linear relationship between seasonal ethylene production and both dry matter production and nitrogen uptake. An average of approximately 4.5 moles of ethylene were produced per mole of nitrogen fixed. Ethylene production during a 4-month period by free-living soil organisms in the rhizosphere of the annual grass soft chess (*Bromus mollis*) was significantly and inversely related to the amount of fertilizer N applied. Ethylene production was significantly higher in the grass rhizosphere than in comparable fallow soils, except where 100 ppm N was applied to the grass cultures.

3148. Vaughn, Charles E., and Milton B. Jones. 1974. **Nondestructive acetylene reduction assays of nitrogen-fixing systems in soil (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 133.
Abstract: A method for conducting short-duration acetylene reduction assays of intact nitrogenase systems in soil was developed. Undisturbed cultures were maintained in 1.6 kg of soil in specially designed polyethylene pots. The pots were sealed and the cultures exposed to an air-acetylene atmosphere which was drawn through the soil during the incubation. No lag period was observed in the ethylene production rates of *Trifolium subterraneum* cultures assayed in this manner. Successively biweekly assays of 30 or 60 minutes duration were conducted on 7 annual *Trifolium* species during complete growth and maturation cycles. There was a significant linear relationship between seasonal ethylene production and both plant top N uptake and dry matter production. An average of 4.5 moles of ethylene was produced per mole of N taken up. Ethylene production during a 4-month period by free-living soil organisms in the rhizosphere of an annual grass, *Bromus mollis*, was significantly and inversely related to the amount of fertilizer N applied. Ethylene production was significantly higher in the grass rhizosphere than in comparable fallow soils, except where 100 ppm N was applied to the grass cultures.

3149. Vaughn, Charles E., and Milton B. Jones. 1976. **Nitrogen fixation by intact annual rangeland species in soil.** Agron. J. 68(4):561-564.
***Abstract*:** The acetylene reduction technique is widely used as an assay of N_2 fixation, but its application to intact N_2-fixing systems in soil has been limited. The purpose of this research was to develop methods suitable for short-duration assays of entire nitrogenase systems and to utilize these methods in studies of N_2 fixation by annual rangeland species growing intact in potted soil. Experiments conducted with nodules excised from subclover plants (*Trifolium subterraneum*) indicated large diurnal variation in acetylene reduction rates; the greatest activity being observed between 1200 and 1600 hours and the minimum at 0400 hours. All standard assays of intact cultures were conducted between 1200 and 1600 hours to standardize light conditions. The pots were sealed, cultures exposed to an air-acetylene atmosphere, and ethylene production was measured. Ethylene production rates of intact subclover plants were linear over a 75-minute period if the gases were mixed during an incubation by pumping a syringe inserted through a rubber serum stopper fitted in the bottom of the pot. Successive biweekly assays of 30 or 60 minutes duration were conducted on 7 species of annual clovers during complete growth cycles. All species exhibited major exponential phases in ethylene production activity which coincided with flowering and seed development. There was a significant linear relationship between ethylene production and both herbage dry matter production and N content. An average of 3.2 moles of ethylene was produced per mole of total plant N contained in 4 subclover cultures. Ethylene production during a 4-month period by soil organisms in the rhizosphere of an annual grass, soft chess (*Bromus mollis*) was significantly and inversely related to the amount of fertilizer N applied. Ethylene production was significantly higher in the grass rhizosphere than in comparable fallow soils, except where 160 mg N (100 ppm) was applied to the grass cultures. The results indicate that these short-duration, nondestructive assays are of value in making quantitative estimates of N_2 fixation. They are particularly useful for repeated samplings of cultures *in situ* during entire growing seasons.

3150. Wagner, Robert E., and Milton B. Jones. 1968. **Ch. 12. Fertilization of high yielding forage crops.** Pp. 297-326 *in:* A. L. Page (ed.), Changing Patterns in Fertilizer Use. Soil Sci. Soc. of America, Madison, WI.
Abstract: This publication describes forage growing areas of the United States, amounts of fertilizer used, potential areas for fertilizer use, quantities of mineral nutrients absorbed, diagnostic techniques by soil and plant analysis combining high yields and quality factors, and modern fertilizer practices on forage crops. It also contains case histories of outstanding forage crop production and discusses barriers to attaining high production.

3151. Wallace, A., Milton B. Jones, and O. R. Lunt. 1975. **Heavy metal uptake by plants from serpentine soils.** Pp. C247-C249 *in:* Proc. Int. Conf. on Heavy Metals in the Environment, Toronto, Canada, Oct. 27-31.
Abstract: Plant samples of native vegetation (*Adenostoma, Quercus*, and *Arctostaphylos*) were collected from serpentine soils in Napa County, California. Subterranean clover (*Trifolium subterraneum*), corn (*Zea mays, B57* and *Oh40B*), and soybeans (*Glycine max* c.v. Hawkeye and P154619-5-1) have been grown on soil from some of those areas under glasshouse conditions. The Mg:Ca ratio in leaves of the native vegetation was quite normal in contrast to agricultural plants. The native plants also contained about 1/10 as much Li, Ni, and Cr as did the agricultural plants. The native plants evidently can endure the unfavorable soil condition, at least in part, because they are capable of behaving like normal plants to the adverse Mg:Ca and trace element conditions. With each of the agricultural crops, 2 different serpentine soils were used and 7 different treatments were used with each glasshouse study, namely: control, Mo (1/10 ppm), chelate (EDDHA, ethylenediamine di(o-hydroxyphenyl-acetic acid)) (2.5×10^{-4} moles per 500 g soil), $CaSO_4$ (1%), $CaCO_3$ (1%), S (½%), and $KHCO_3$ (500 ppm K). These provided a gradient in cations and trace metals in plants so that the correlation coefficients between yield and elemental composition of plants could be calculated. It is noted that r^2 always totaled more than 1.0 so some of the relationships are coincidental. The agricultural plants not adapted to the area were high in Mg, Zn, Fe, Ni, Cr, and sometimes Co. Plant yields were related to the levels of trace elements other than Ni, Cr, and Co, especially Zn, Mn, Cu, and Fe. Serpentine soils present interesting situations where adaptation of plants to high levels of

heavy metals can be studied. There are many species of plants which have become adapted to the serpentine soil conditions and others which can tolerate the conditions. Such soils can be used as models for long-time effects of trace element contamination.

3152. Wallace, A., Milton B. Jones, and G. V. Alexander. 1982. **Mineral composition of native woody plants growing on a serpentine soil in California.** Soil Sci. 134(1):42-44.
Abstract: Using optical emission spectography, we analyzed leaves of five native plant species, *Adenostoma fasciculatum, Arctostaphylos viscida, Cupressus macnabiana, Cupressus sargentii*, and *Quercus durata*, for mineral elements. In these plants, which are reasonably adapted to serpentine soil conditions, the calcium to magnesium ratios were normal in contrast to plants not adapted to such soil conditions. The nickel concentrations in the leaves were low for serpentine soil conditions, and there was no tendency for accumulation of chromium or cobalt. Strontium varied, as did calcium.

3153. Williams, William A., Milton B. Jones, and C. C. Delwiche. 1977. **Clover N-fixation measurement by total-N difference and ^{15}N A-values in lysimeters.** Agron. J. 69:1023-1024.
Abstract: Assessment and improvement of N fixation by legumes on annual-type range is becoming increasingly important in light of the increasing need for energy conservation. A comparison was made of two methods assessing N fixation: a simple but crude method by measuring the total-N difference in tops of an N-fixing legume and a non N-fixing grass, and a more expensive method using A-values determined from ^{15}N applications to the same legume and grass species. Subterranean clover (*Trifolium subterraneum*) and soft chess grass (*Bromus mollis*) were grown in field lysimeters (69 cm deep by 36 cm diam.) filled with Josephine loam (Typic Haplozerults, fine loamy, mixed mesic) for 3 years. Single (100 and 500 kg/ha) and repeated (100 kg/ha) applications of ^{15}N were made and determinations were made of soil and fertilizer N in the plants, soil, and leachate periodically. The relation between the two methods was strongly linear; fixation (kg/ha) by the A-value method = 50.1 + 0.852 N fixation by difference (r = 0.98, n = 15). Consequently, previous values cited for N fixation measured by the difference method for winter annual legumes in California may have been underestimated by about 40%.

3154. Williams, William A., Milton B. Jones, and Montague W. Demment. 1990. **A concise table for path analysis statistics.** Agron. J. 82:1022-1024.
Abstract: The use of path analysis is expanding rapidly by practitioners of the biological and agricultural sciences because of the insights it generates from correlational structures. However, the process of interpretation can be tedious as well as difficult. A concise format for presenting path analysis statistics is demonstrated in which the path coefficients are placed in the main diagonal of a matrix, and the indirect effects are placed as off-diagonal elements. This arrangement makes it easier to compare within and among path analyses than with the currently used format, thus facilitating interpretation.

3155. Yeilding, E. Linton. 1977. **Decomposition in chaparral.** Pp. 419-425 *in:* Proc. Symp. Environ. Consequences of Fire and Fuel Management in Mediterranean Ecosystems (H. H. Mooney and C. E. Conrad, tech. coords.), Palo Alto, CA. USDA For. Serv., Gen. Tech. Rep. WO-3.
Abstract: Decomposition rates were measured by a polyester bag technique. Rates in percent weight loss are compared for 3 species (*Quercus dumosa, Adenostoma fasciculatum, Ceanothus greggii*), 7 fuel classes (foliar and woody stem diameter classes), and 3 positions (buried, surface and aerial). Differences in rates were shown for species, between foliar and woody fuel classes, and position. Analysis of initial nutrient content showed differences between fuel classes but not species. The variables then that are responsible for decomposition rates are probably multiple, including nutrients as well as environmental factors.


Colin Brooks

Research controlled burn in chaparral, Orchard Pasture, November 1999

3156. Yeilding, E. Linton. 1981. **Decomposition of fire fuel components of seven southern California chaparral plants.** M.S. Thesis, Univ. Calif. Berkeley. 141 pp.
Abstract: Decomposition rates of 7 fuel diameter classes (ranging from less than 0.5 cm to 2.5 cm in diameter) and 3 exposure positions (buried, surface and aerial) were determined for 7 chaparral species. Decomposition was expressed as cumulative dry ash-free, weight lost, determined over 6, 12, 18 and 24-month time periods, by a polyester bag technique. Exposure position was the most significant factor affecting decomposition rate with buried samples decomposing faster than surface and aerial samples. All effects of position, fuel diameter class, and species were significant, and statistical interaction occurred between these factors. Analysis of interactions showed that burial caused much more rapid decomposition of plant material than unburied material (surface and aerial). Foliage decomposed more rapidly than other fuel classes. The fine woody fuel classes decomposed significantly faster in some cases, but not all, than the heavier woody fuels. A separation of means showed that foliage almost always decomposed at the highest rate. Woody tissues, considered as a group, decomposed at a slower rate, while fine woody fuel classes decomposed at intermediate rates in most cases. Red shank (*Adenostoma sparsifolium*) decomposed more rapidly than the other species in many cases but not all cases. Decomposition rates had to be evaluated by the species and respective fuel classes separately. Decomposition rates did not closely fit either of the constant rate models of Olsen or Radford types. Buried samples fit these models more consistently than surface or aerial exposed fuel components. The best expression of decomposition rates were the percent lost estimates for each time period (Jenny's Model).

3157. Young, James A., Raymond A. Evans, and Burgess L. Kay. 1970. **Phenology of reproduction of medusahead.** Weed Sci. 18(4):451-454.
Abstract: The phenology of reproduction was highly variable among 23 selections of medusahead (*Taeniatherum asperum*) collected from locations in Washington, Oregon, Nevada, and California (including Hopland). Selections with markedly early and late maturity were observed. The phenology generally was consistent during 4 years of testing at Reno, Nevada, and during 2 years at Davis, California. Individual selections differed greatly in phenology between two locations. Some of the selections exhibited phenotypic plasticity in phenology when grown in competition with other weeds.

A. H. Murphy

4001. Adams, David R. 1977. **Environmental and hormonal control of chamise (*Adenostoma fasciculatum*) shoot growth.** M.S. Thesis, Univ. Calif. Davis. 52 pp.
Abstract: The seasonal cycle of shoot growth in chamise involved an active period of growth from January through May, and a period of quiescence through October. Growth was inhibited in November and December when moisture was suitable for growth. Low temperature probably enforced quiescence at this time. Tissue culture experiments demonstrated that sucrose was required for apical growth of chamise shoot tips, with an optimum concentration of 6% for shoot tips excised from rapidly growing plants. A cytokinin, benzyladenine, promoted shoot growth at otherwise growth limiting sucrose concentrations by inducing sucrose uptake from the basal medium. Abscisic acid and infusion from chamise leaves inhibited growth of cultured shoot tips induced by both high sucrose concentrations or benzyladenine. These experiments suggest that quiescence may be maintained by a reduction in the availability of carbohydrates to the shoot apex, a decrease in the level of cytokinins at the apex, or an increase in the level of inhibitors in the shoot tips.


A. H. Murphy

HFS foreman Fran Lile examines sprouting scrub oak invading an area of chaparral conversion, James III Pasture near Hog Lake, April 1967

4002. Adams, Theodore E. 1979. **Brushland management.** Calif. Agric. 32(10):9.
Abstract: Brush is a major vegetation type in California. Brushlands are dynamic systems which developed with the aid of fire over millions of years. In the past, concern with wildfire has provided the central focus for brushland-related research. New methods to enhance and protect our brushlands resource are being investigated. Animals may be used in brush management programs to help reduce wildfire hazard and provide for human needs in an energy-efficient program. There is growing need to determine the response of brushland communities and brushland soils to various management programs to produce multiple effects. Information from these efforts will help improvement management techniques that protect and enhance brushlands. There are a wide spectrum of values and interests represented in California's brushlands.

4003. Adams, Theodore E. 1991. **Planting blue and valley oak acorns and nursery stock on oak-grassland range.** Pp. 168-177 *in:* Selected Techniques for Restocking Hardwood Rangelands in California with Native Oaks. Report submitted to CA Dept. of Forestry & Fire Protection, Sept. 10, 1991. Integrated Hardwood Range Manage. Program, Dept. For. and Resour. Manage., Univ. Calif. Berkeley.
Abstract: While procedures for propagation, culture, and management of oaks in controlled environments have been developed, relatively little is known about how to successfully establish native California oaks in a wildland setting. Factors that limit natural seeding recruitment can also prevent planted acorns and seedlings from surviving and growing. This study evaluated several planting and protection procedures. The specific objectives were to compare the field performance of directly sown acorns with 2- to 3-month-old nursery stock, all planted under weed-free conditions, and to determine whether insect and small mammal protection is necessary for restocking areas where livestock graze. The information from this study will help define what practices are most effective for restocking oak grasslands with blue and valley oaks.

4004. Adams, Theodore E., and Peter B. Sands. 1999. **Clipping chamise reduces brush fire hazard.** Calif. Agric. 53(3):25-29.
Abstract: Wildfire is a particular concern where housing and business development encroaches on highly flammable brushlands. In these areas, it may be risky to use prescribed fire to control biomass and reduce the fuel for a fire. Chamise chaparral, the most common of the brush types, at Hopland was clipped to study how biomass removal affects flammability and fire hazard. The results suggest that infrequent clipping of chamise to a height of 12 inches may adequately reduce fuel volume and encourage new growth high in moisture, which lowers the flammability of vegetation.

4005. Allen, Barbara H., Barbara A. Holzman, and Rand R. Evett. 1991. **A classification system for California's hardwood rangelands.** Hilgardia 59(2):1-45.
Abstract: A hardwood rangeland classification system for California is described. The system provides private landowners, land managers, and researchers a unifying framework from which known ecological and management information can be retrieved. Standardization of type names facilitates the exchange of information on hardwood rangelands within and among agencies, landowners, and universities. The dichotomous keys to the type descriptions ensure that the system is field oriented and user-friendly. The classification system consists of 57 subseries arranged hierarchically within 7 series. The Oak Series are defined by the dominant oak species present on the site. A Mixed Oak Series is also defined from sites that contain three more species of oak at constancies of greater than 30%. This system does not include subseries descriptions for Englemann or Garry oak types. The base information on species composition, percent cover by species, tree stand structure, and environment was collected on 1/5-acre plots. Species cover was determined from a 33' by 66' belt transect on each plot. The classification structure was developed using TWINSPAN, a polythetic, divisive classification program developed by Hill. Further analyses were performed using DECORANAS, and frequencies, regression, and analysis of variance. The information contained in the final type descriptions was developed from VTM data only. The keys and type descriptions have been field tested and verified at several locations in the state, such as Hopland Field Station, Sierra Field Station, Hastings Reserve, and the San Joaquin Experiment Station. The tests were conducted by individuals familiar with hardwood rangeland ecosystems and those who were not. Ongoing use of the keys and descriptions in other parts of the state will provide information for further refinement of keys and descriptions. Additional information on potential productivity and response to management will be incorporated into the descriptions by users as they identify the types that they are working in by the classification subseries names.

4006. Allen-Diaz, Barbara H., and James W. Bartolome. 1992. **Survival of *Quercus douglasii* Fagaceae seedlings under influence of fire and grazing.** Madrono 39(1):47-53.
Abstract: Recent burning and sheep grazing did not affect recruitment, survival, or growth of seedling *Quercus douglasii* over four years at the Hopland Field Station, California. Recruitment did not vary considerably among years. Once a seedling's shoot emerged, the probability of surviving to the next year remained constant, at about 0.5, unaffected by year, seedling size, or age, past fire, or present sheep grazing. Established seedlings did not increase in size and showed no indication of growing out of the seedling class into the sapling class. Successful natural regeneration appears to depend on factors controlling growth, not on factors associated with mortality during the seedling stage.


Robert M. Timm

HFS staff supervisor Ken Whittaker lights chaparral with drip torch during controlled burn, Spring 1976

4007. Anonymous. 1988. **University of California Hopland Field Station.** Pp. 4-5 *in:* M. R. Haferkamp, P. O. Currie, J. Menke, and B. Zamora (eds.), Range Research Areas in the Western United States. Agric. Expt. Stn. Bull. 671, Oregon St. Univ. and Western Regional Coord. Comm. 40, Corvallis, OR.
Abstract: Describes the Hopland Field Station, as one of 25 range research facilities described within the 11 western states. Information summarized includes location, facilities, size, history, physical features (soil, vegetation, climate, elevation), and research emphasis. Data collections available are outlined and future research plans are noted.

4008. Barlow, B. L. 1997. **A land-use management plan: examples from a UC research center.** Oaks 'n' Folks 12(1):3.
Abstract: A voluntary program in under way in California for private ranchers to assess conditions on their land that may be contributing to non-point-source water pollution, including sediment, nutrient, and pathogen loading. A land-use management plan was developed for the Hopland R & E Center. The plan was written with 3 main purposes: 1) to bring HREC into voluntary compliance with the Rangeland Water Quality Management Plan of the State Water Resources Control Board, 2) to develop guidelines that would assist HREC managers to maintain healthy ecosystems, and 3) to serve as a model for other landowners having similar resources. The plan addresses issues such as water quality, pasture use, hardwood stand dynamics, invasive weedy species, erosion and sediment control, and the presence of sensitive plant and animal species. Recommendations to aid in sustainable resource management, such as methods for restoration of specific riparian areas, are included.

4009. Bartolome, James W., M. C. Stroud, and Harold F. Heady. 1980. **Influence of natural mulch on forage production on differing California annual range sites.** J. Range Manage. 33 (1):4-8.
Abstract: Manipulation of natural mulch on nine experimental plots in California annual grassland representing a range of mean annual precipitation from 160 to 16 cm provided information useful for grazing management. Peak standing crop correlated highly significantly with precipitation. Response of peak standing crop to five levels of natural mulch ranging from 0 to 1,120 kg/ha differed with site. Three types of sites distinguished by mean annual precipitation and plant species composition were identified. On sites with significant numbers of perennial grasses and more than 150 cm of mean annual precipitation, maximum standing crop is reached when more than 1,120 kg/ha of mulch is present on the ground at the beginning of the fall growing season. Peak standing crop results from 840 kg/ha of mulch on sites containing the annuals *Bromus mollis* and *Erodium botrys* and with between 10 and 65 cm of mean annual precipitation. Mulch did not significantly influence standing crop in regions dominated by *Bromus rubens* and *Erodium cicutarium* and receiving less than 25 cm of mean annual precipitation. Annual grass and response to mulch and grazing is highly site specific, yet the resilience of annual rangelands also allowed rapid recovery from overuse.

4010. Bartolome, James W., and M. P. McClaran. 1992. **Composition and production of California oak savanna seasonally grazed by sheep.** J. Range Manage. 45(1):103-107.
***Abstract*:** Seasonal grazing trials, conducted over three years at the Hopland Field Station, tested the effects of two seasonal grazing strategies on within- and between-year production and composition in blue oak (*Quercus douglasii*) savanna understory and adjacent open annual grassland. Moderate intensity summer-fall-winter and spring-summer sheep use had few within-year effects. In contrast, production and composition varied considerably between years in both treatments. Forbs (especially legumes) decreased in open grassland and oak understory between years within both seasonal grazing regimes. This change could not have been caused by selective grazing because there were no corresponding within-year patterns. Instead, between-year changes are more likely related to nonselective effects of stocking rate and/or weather. Results from this study suggest that seasonal grazing systems offer little potential for improvement of annual range composition.

4011. Beaton, James D., Robert L. Fox, and Milton B. Jones. 1985. **Ch. 11. Production, marketing, and use of sulfur products.** Pp. 411-453 *in:* O. P. Engelstad (ed.), Fertilizer Technology and Use. Soil Sci. Soc. of America, Madison, WI.
Abstract: Interest in sulfur as a plant nutrient has increased in recent years. Widespread S deficiencies have been demonstrated worldwide. Increasingly effective pollution control measures and the manufacture of high-grade, low-S, phosphorus fertilizers have aggravated these deficiencies. The interest in S fertilization extends beyond increasing crop yields, however. Low crop content of the essential S-containing amino acids is a matter of serious concern in many less developed areas of the world. Sulfur has other beneficial side effects in addition to its role as a plant nutrient. The acidifying effects of many S fertilizers may increase the availability of other essential nutrients such as P, Mn, and Zn. Sulfur is useful in reclaiming sodic soils, and many S materials are used for treatment of irrigation water to improve water infiltration and percolation. The topic of production, marketing, and use of these S products is reviewed in this chapter.

4012. Bell, Monte. 1988. **Oaks and range livestock feed.** Oaks 'n' Folks 3(2):4-5.
Abstract: The article summarizes data on acorn and oak leaf intake of sheep and cattle at Hopland, as measured by Van Dyne and Heady in 1965 using animals with esophageal fistulas. It also cites mast crop productivity measurements made at Hopland by Longhurst (1979) and by Menke (1975). Menke's studies of yearling ewe

weight gains when fed acorns to supplement dry grass are noted. Acorns can supply energy to livestock, if properly supplemented with protein, calcium, phosphorus, and vitamin A, or with green grass. However, tannins in acorns can interfere with digestion, and high tannin levels in leaf buds can be toxic to cattle in some instances. Whether or not to think or remove oak trees on rangeland is a difficult decision. The Holistic Resource Management (HRM) model is useful when considering such choices.

4013. Besga, G. S., V. V. Rendig, L. Domingo, and Milton B. Jones. 1985. **Effects of applications of S and Se on the composition of pasture forage (Abstract).** P. 10 *in:* Agron. Abstr., Am. Soc. Agron., Madison, WI.
Abstract: In the coastal counties of northern California, USA, S deficiencies of forages are widespread. Sulfur fertilization under these conditions has resulted both in increased yields and in improved quality as measured by in-vitro digestibility and by weight gains of sheep fed the forage as hay or grazing pastures in the area. However, a S/Se interaction was indicated from blood Se levels found in sheep grazing pastures to which various rates of S as gypsum had been applied. Generally, lower blood Se levels were associated with lower Se concentrations in forage from pastures to which S had been applied. Concerns as to adverse effects on animal nutrition prompted further investigation. Yield responses and concentrations of S and Se were determined in subterranean clover (*Trifolium subterraneum*) and ryegrass (*Lolium multiflorum*) grown in field plots to which elemental S or gypsum were added alone, or in combination with two levels of Se applied as selenate. Sulfur additions, either as elemental S or as gypsum, approximately doubled yields of forage. The S concentrations in both forage species were increased with both sources of S, the elemental form tending to have a slightly greater effect. The Se concentrations in both forage species grown on the S-fertilized plots were lower than in forage from plots not receiving S additions. The negative interaction was somewhat greater with the gypsum treatment. The response appears to be a combination of growth dilution effects and ion competition.

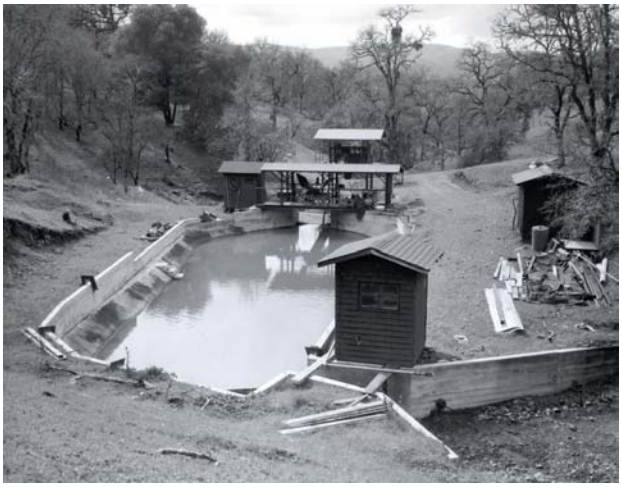
4014. Besga, Gerardo S. 1987. **Sulfur and selenium interactions in uptake and assimilation by annual ryegrass and subclover.** Ph.D. Dissertation, Univ. Calif. Davis. 235 pp.
Abstract: Annual ryegrass (*Lolium multiflorum*) and subclover (*Trifolium subterraneum*) are important plant species in improved pastures. Sulfur (S) fertilization of pastures where soil S levels are inadequate for plant growth increases forage yields as well as feeding quality. However, in locations where soil selenium (Se) levels are low, S additions may decrease Se concentrations in forages to levels inadequate for animal requirements. The objective of the studies described here is to define soil and plant factors that influence the extent to which plant Se concentrations reflect S and Se concentrations in the plant growth medium. The hypothesis tested was that both uptake and assimilation mechanisms, which may differ quantitatively or qualitatively between species as well as varieties, should be considered in defining the S/Se interaction. Sulfur and Se uptakes were compared in ryegrass and subclover under greenhouse conditions. Gypsum and elemental S effects on uptake of native and applied Se by ryegrass and subclover were studied under field conditions. Finally eight subclover varieties were tested for Se uptake differences in nutrient solutions. Shoot Se concentrations were generally decreased by S additions, with gypsum showing the greater effect. However, a synergistic effect of S on Se uptake occurred during periods of fast plant growth for some of the S treatments. Root Se concentrations, because S and Se compete both in uptake and translocation to the shoot, either increased or decreased. Subclover root Se concentrations were higher than those in ryegrass, and an undefined linkage of rhizobial nodulation to Se applications through yield responses was indicated. Selenium and S concentrations were positively correlated in the eight subclover varieties, but genotypic differences were reflected in their plant concentrations. Sulfur concentrations were affected by S and Se additions. On several occasions at the highest level of applied S, because of decreased Se uptake, S concentrations decreased showing their interaction in plant metabolism. In summary, defining quantitatively the S/Se interaction in plants requires consideration of the relative levels of S and Se available for uptake and present in plants, yield responses to S additions, root/shoot relationships, and species and varietal differences.

4015. Brock, Elbert M., and Walter E. Howard. 1960. **Responses of rodents to range fertilization.** Pp. 60-62 *in:* Proc. Ann. Mtng., Calif. Sect., Am. Soc. for Range Manage.
Abstract: When meadow mice, *Microtus californicus*, were given a choice of fertilized or unfertilized forage in experimental cages, they greatly preferred the fertilized grasses. We believe that this choice was primarily due to the more dense growth and better cover found on that side, and that the feeding on fertilized forage was a secondary factor. Extensive snap trapping on treated and untreated rangeland in California showed that meadow mice do not become established on fertilized range because of the intensive grazing that the range receives. Although the forage would be more abundant on treated range, the grazing by sheep and cattle soon convert it into a habitat not suitable for meadow mice. Trapping revealed a tendency for fewer rodents on fertilized pastures both during the fall check when forage was dry and during the spring when the grasses were growing. Of the 163 rodents caught, 103 were from the untreated pastures. Most of this catch consisted of deer mice, *Peromyscus maniculatus*, and it appears that perhaps fertilization of rangeland may decrease their numbers. Data showed no difference in weights or skeletal measurements of rodents inhabiting rodent nesting boxes on fertilized pastures as compared to rodents in unfertilized pastures grazed by sheep.

4016. Brooks, Colin N., and Adina M. Merenlender. 1998. **Characterizing the spatial pattern of vegetation regeneration in a cleared watershed.** *In:* Eighteenth Annual ESRI User Conf. Proceedings, San Diego, CA. 23 pp.
Abstract: Many of California's watersheds have been cleared of their trees and brush for the benefit of livestock since 1945. These clearings have lead to problems with ecosystem health, including a lack of regeneration of some tree species, loss of topsoil, and altered water regimes. There is a need for active restoration to improve ecosystem function in these watersheds, which could be completed more effectively if the patterns of natural regeneration were better understood. This study uses geographic information systems (GIS) and remote sensing to characterize the spatial pattern of natural vegetation regeneration in a watershed of the Hopland Research and Extension Center. The watershed was cleared of most of its tree and brush cover in the early 1960s and sheep have grazed the site intensively since that time. Both physiographic and biological characteristics of regeneration were analyzed. The methods described here could be used by other researchers at a variety of scales when investigating regeneration. With a better understanding of natural regeneration, restoration efforts could be concentrated on areas and vegetation types less likely to come back by themselves. Physiographic GIS data including slope, aspect, and soil type were analyzed in Arc/Info and ArcView, revealing an association of hardwood regeneration with moister sites such as steep, northwestern slopes and riparian zones. A nearest neighbor distance analysis was completed using a modified Avenue program in ArcView. The distribution of trees in the watershed was statistically clustered, implying that mature trees are having a positive effect on the establishment of new trees through provision of shade, protection, and seeds. Evergreen oaks, located on moister northerly-facing slopes, have been re-establishing themselves with greater success than deciduous oaks, which are located mostly on drier, southerly-

facing slopes and are also more susceptible to grazing pressure. Restoration efforts in similar areas should focus on planting and protecting vegetation on drier slopes, particularly for poorly-regenerating deciduous oaks.

4017. Brooks, William H., and Alfred H. Murphy. 1974. **Increasing winter feed on the North Coast of California.** Pp. 614-620 *in:* Proc. XII Int. Grassland Congr., Moscow, U.S.S.R.
Abstract: Winter and early spring range feed production by subterranean clover (*Trifolium subterraneum*) can often be significantly increased by planting a mixture of subclover varieties instead of a single variety. Geraldton had the highest yield of any single variety in late winter harvest, Mt. Barker highest yield for any individual variety in spring or early summer, Woogenellup filled the gap between the above two, and Tallarook was best for coastal locations. Subclover varieties tested have relatively short periods of high production thus a mixture of varieties takes advantage of these production peaks resulting in significant increase in early feed and total feed production.


A. H. Murphy
Watershed II collection basin, February 1957

4018. Burgy, Robert H. 1958. **Water yields as influenced by watershed management.** Pp. 1590-1 - 1590-10 *in:* J. Irrigation and Drainage Div., Proc. of the Am. Soc. of Civil Engineers, San Francisco, CA, April 1957.
Abstract: Hydrologic studies on small brush-covered watershed in the Coast Range and Sierra Nevada mountains of California show that appreciable increases in runoff can result from replacement of brush by grass. Water yield increases of as much as 10 inches have been measured under favorable conditions without serious acceleration of soil erosion. These management practices also result in improved forage production on previously marginal land. Factors in precipitation disposal are discussed in relation to the influence of watershed vegetation on runoff.

4019. Burgy, Robert H. 1957. **Watershed management in relation to water yield. II– Water yields as influenced by vegetation management on watersheds below snowline.** Proc. 1st Intersociety Conf. on Irrig. and Drainage, San Francisco, CA, pp.19-23.
Abstract: Researchers from the University of California have been engaged for some time in studies to attempt to develop vegetation manipulation techniques which produce a beneficial response in increased water yield without undesirable effects. Removal of the primary intercepting vegetative canopy permits a greater amount of precipitation to reach the soil surface. However, increased runoff occasioned by the additional precipitation arriving at the soil surface and contributing to a greater quantity of surface and subsurface runoff may create situations of increased movement of debris down channels, as well as higher erosion rates. As of 1957, we have under study seven major watershed installations involving either single watershed complexes or pairs. These are located from Shasta County in the north to Tulare County in the south, in both the Sierra Nevada and Coast Range foothills, and include two sites at the Hopland Field Station. We have learned that the soil type, vegetative cover, geographical location, and character of storms producing the runoff all have profound influence on the hydrologic responses of these watersheds. The data available presently are only for small watersheds (less than one to approximately 20 acres). Current studies on larger watersheds such as those at Hopland should give a better picture of the situation.

4020. Burgy, Robert H. 1958. **The erosion hazard in obtaining increased water yields on dry lands.** P. 18 *in:* Am. Soc. of Agric. Eng. 5lst Ann. Mtng., Santa Barbara, CA, Jun. 23-25.
Abstract: These pilot watershed studies provide basis for evaluation of the potential hazard of increased erosion in vegetation management. On many of the sites tested, the magnitude of the increase in erosion is relatively small. In all but one case, rates have been reduced after establishment of grass on the areas. Other control techniques like supplemental debris traps may prove beneficial in minimizing the risk of temporarily accelerated erosion. Thorough planning based on good information and understanding of these natural processes will permit the design and application of watershed management programs for the best utilization of the potential resources of our watersheds with minimum risk.

4021. Burgy, Robert H. 1958. **Hydrologic studies on California brush lands**. Presented at: Joint Hearings of the Senate Interim Committee on the Economic Redevelopment of Cut-Over Timber Areas and Brushlands and Senate Interim Committee on Forest Practices, Sonora, CA, May 22.
Abstract: *see* Burgy 1958. Am. Soc. of Agric. Eng. 51st Ann. Mtng.

4022. Burgy, Robert H., and C. R. Pomeroy. 1958. **Interception losses in grassy vegetation.** Trans. Am. Geophysical Union 39(6): 1095-1100.
Abstract: Studies of the interception process in grassy species are reported for a series of laboratory tests. Procedures, equipment, and techniques were developed to determine the magnitudes of rainfall interception on grasses and to measure the resultant losses. It was found in vigorously growing grass plots that the evaporation of a given amount of intercepted moisture was accompanied by a like reduction in the amount of evapotranspiration from the plants. Total moisture use was approximately the same in plots with wet and dry leave surfaces. The interception storage component and precipitation passing through the vegetative canopy as combined stream flow, throughfall, and drip (STD) were measured to determine the relationship and magnitudes. Storage capacities were observed to agree essentially with those reported by other investigators although some variations can occur with different storm types and intensities. Values of STD were found to be quite significant even at the beginning of small storms.

4023. Burgy, Robert H. 1966. **Range improvement aids flood control.** Univ. Bull. (Staff). 14(39):251.
Abstract: Stream flow has been increased, flood runoff peaks have spread out, and fire hazard has been reduced on a 210-acre watershed at the Hopland Field Station. These gains, plus an expected increase in forage production, have come about through manipulation of the vegetation. Reported to a Field Day audience were the effects of removing oak trees and madrone trees from the watershed. The trees have been replaced by a range mixture of grasses and legumes. There have been some serious “slips” on the watershed, which could

be normal or could be a result of removing trees. There is good erosion control on the grass slopes. Some soil slips more than others, and its too early to say what effect the treatment had. Two hundred fifty tons of sediment from the watershed were measured in the 1964-65 winter floods, before the watershed was burned. It now takes twice as long to get the runoff out of the watershed as it did before the treatment. We attributed this to the change from tree to grass cover. This kind of management appears advantageous in reducing flood peaks.

UC Davis hydrologist Robert Burgy at stream gate following controlled burn, Watershed II, July 20, 1965

4024. Burgy, Robert H. 1968. **Hopland experimental Watershed II.** Section 3, pp. 1-22 *in:* Hydrologic studies and watershed management on brushlands. Ann. Rep. #8 (1966-67), Dept. of Water Science & Civil Engineering, Univ. Calif. Davis.
Abstract: The research program described here has been underway for sixteen years. The significance of the increased productivity occasioned by the management work on Hopland Watershed II is obvious. Nine times more forage and livestock are produced. Over 4 inches of average annual water yield has been produced. In given years the magnitude is of the order of 10 inches. It must be recognized that the increased yield is derived from lands which are producing useful forage vegetation, whereas previous growth of oaks and brush species had very low economic value. The striking increases in water yield, 1½ times the prior amounts, provides year-round water supply to the grazing unit. The timing of increases in runoff is indicated to be advantageously delayed after rainfall events and is produced at lower rates. Base flow is produced at higher rates in the entire season, the stream continuing to flow throughout the dry season. Data presently in hand indicates the quality of the runoff water was maintained. Erosion rates were seriously influenced by the 1964-65 record storms. The damages created by land slips in that event have largely diminished and erosion rates are tending to resemble pre-treatment experience. Possibilities of correlation of the several kinds of basic data collected in this study area are tremendous. Many relationships are being derived and the composite picture of watershed land use-vegetation-livestock and climatic interactions are emerging.

4025. Burgy, Robert H. 1968. **Hydrologic studies and watershed management on brushlands. A summary of research progress and accomplishment.** Section 3, pp. a-c *in:* Ann. Rep. #8 (1966-67), Dept. of Water Science & Civil Engineering, Univ. Calif. Davis.
Abstract: This report summarizes hydrologic research on means of increasing water yields through management of vegetation. Three study areas, namely Watershed II at the Hopland Field Station, Mariposa Piney Creek Watershed, and the Placer Co. Experimental Watersheds, show average increases of 50% in seasonal runoff. Magnitudes range from 2 inches to >16 inches with overall average yield increases between 4 and 5 inches per year. Section 3 of this report contains extensive descriptive information about the Watershed II study area at Hopland, including physical descriptions, vegetations, soils, geology, and hydrologic facilities developed at this site. Treatments to convert existing vegetation to grassland, which was accomplished by killing trees by herbicide application and subsequent controlled burning of the entire watershed, are described in detail. Reseeding to a mixture of grasses and legumes followed, with subsequent management to enhance forage for livestock grazing. The research study encompasses 16 years, representing the most comprehensive investigation of the total effect of man's cultural activities on foothill lands that has been attempted in the University's hydrologic research program. Further, it represents the only long-term research study underway in the North Coastal Region of California that is capable of providing useful hydrologic results. Because only 2 years of data are now available for the present treatment phase, the conclusions are considered as tentative and must be so interpreted. The significance of the increased productivity in Watershed II is obvious. Nine times more forage and livestock are produced. The value of this is readily determined by economic analysis. Over 4 inches of increased annual water yield has been produced. In given years, the magnitude is of the order of 10 inches. It must be recognized that the increased yield is derived from lands which are producing useful forage vegetation, whereas previously, growths of oak trees and brush species had very low economic value. The striking increases in water yield, 1½ times the prior amounts, provide year-round water supply in the grazing unit. The timing of increases in runoff is indicated to be advantageously delayed after rainfall events and is produced at lower rates. Base flow is produced at higher rates in the entire season, the stream continuing to flow throughout the dry season. Data presently indicate the quality of the runoff water is maintained. Erosion rates were seriously influenced by the 1964-65 record storms. The damages created by land slips in that event have largely diminished and erosion rates are tending to resemble pre-treatment experience. Possibilities of correlation of the several kinds of basic data collected in this study are tremendous. Many relationships are being derived, and the composite picture of watershed land use-vegetation-livestock and climatic interactions are emerging.

4026. Burgy, Robert H., and Z. G. Papazafiriou. 1970. **Hydrologic studies and watershed management on brushlands.** Progress Rep. #9, Dept. of Water Science & Civil Engineering, Univ. Calif. Davis. 31 pp.
Abstract: Annual precipitation runoff and water yield from experimental watershed sites show a significant change in watershed performance after alteration of the ambient vegetation from deep rooted trees and brush to native and introduced grasses. Average annual runoff over the treatment periods in all tests gave nearly 5 inches of increased yield. Hopland Watershed II was subjected to a multiphased management sequence and after 4 years of experience in a fully converted configuration, now indicates nearly 90% increase in annual runoff; 50% resulting from tree-killing operations (1960-65) and nearly 40% subsequent increase following trash removal by controlled burning (1965) and revegetation with grasses. Substantial increases in direct storm runoff occur during fall and winter periods with grass cover, while during spring conditions the direct runoff component is diminished; base flow of these streams shows significantly greater dry season flow.

4027. Burgy, Robert H., and Z. G. Papazafiriou. 1971. **Effects of vegetation management on slope stability, Hopland experimental**

Watershed II. Rep. Water Resour. Cent. Advis. Counc. Mtng., Sacramento, CA. 7 pp.
Abstract: Description of Watershed II is given as well as the three phases of management used. Area was stable prior to treatment but for two years following treatment 61 soil slips occurred. The soil slips were identified as two types: failure of slopes along a failure plane; and soil mud due to liquefaction. Removal of tree cover and substitution of grass resulted in: 1) removal of mechanical reinforcement provided by roots of trees; 2) increased runoff, higher streamflow peaks, increase of suspended sediments caused more bank scouring and cutting; 3) decay of tree roots resulted in piping, subterranean erosion; 4) higher soil moisture, saturated zone increases; and 5) increased seepage. Observation in Watershed II in regards to landslips indicated that: all landslips occurred in the vicinity of stream channels; bank cutting preceded land slides; minimum slope gradients where landslips occurred were approximately 45 degrees; and number of slips were directly proportional to the amount of rainfall at each interval. Occurrence of mud flows at certain sites may be associated with land tremors. Maps of slips, soils, and topography as well as charts of rainfall and graphical presentation of soil mass movement genesis are presented.


A. H. Murphy

Superintendent Al Murphy and pilot confer before aerial seeding of Watershed II, Lower Strip Pasture, November 1959

4028. Burgy, Robert H., and Z. G. Papazafiriou. 1971. **Vegetative management and water yield relationships.** Pp. 315-331 *in:* Proc., 3rd Int. Seminar for Hydrology Professors, Purdue Univ., W. Lafayette, IN, Jul. 18-30.
Abstract: Vegetation is related to the runoff cycle through evapotranspiration and interception. Both processes are direct functions of the type and density of vegetation. The response of watersheds to interception reduction is rapid and can be clearly visualized by storm hydrograph analysis. Statistical methods, in general, are the most useful tools in evaluating watershed responses to vegetative treatment. Seasonal distribution of precipitation is an important factor affecting total annual water yield; March appears to be the critical month on the runoff process in Northern California. Estimated average increases in water yield after vegetation management range from 50 to 80% in central and northern California, reflecting the average annual increase in the order of 4 acre inches.

4029. Carneggie, David M., Stephen D. Degloria, and Robert N. Colwell. 1974. **Usefulness of ERTS-1 and supporting aircraft data for monitoring plant development and range conditions in California's annual grassland.** Final Report, Contract No. 53500-CT3-266(N) for Bureau of Land Management, U.S. Dept. of the Interior. Remote Sensing Research Program, Sch. of Forestry and Conservation, Univ. Calif. Berkeley. 53 pp.
Abstract: This report describes feasibility studies using Earth Resource Technology Satellite (ERTS) imagery to 1) monitor growth and development of annual plants; 2) determine relative amounts of forage produced on a given area between years; 3) locate and map areas of different forage producing potential; 4) predicting forage condition and production. ERTS imagery and ground data collected at 16 California sites (including the Hopland Field Station) for the 1972-73 growing season. The results of ground spectral reflectance data compared with green forage production data show a close correspondence between spectral reflectance ratios and green biomass. Changes in ground spectral reflectance data also correspond with observed changes in growth stage and condition of the forage species. Moreover, ERTS spectral reflectance data provides quantitative signals of significant growth stages in the development of annual forage species. Relative- differences in forage production are also indicated by the ERTS spectral radiance data. Provided that cloud free ERTS coverage is available during critical growth stages of the annual plants, namely germination, peak of foliage production, and period of maturation and drying, ERTS data can be used to assess differences in range condition on a regional basis, and compare differences in production between grazing regions. The length of the green feed period can be determined and this information, along with ground samples of forage production and climatic data, can provide the inputs to simple models for estimating forage production or determining the remaining length of the green feed period beyond a definable threshold date late in the growth cycle of the annuals. ERTS color composite images provide a visual picture of the condition of the rangeland. Repetitive sequences of these images provide the means for monitoring change in condition and comparison of condition of different range areas.

4030. Center, D. Michael, Milton B. Jones, and Charles E. Vaughn. 1982. **Effects of sulfur, nitrogen, and clipping on competition between two annual grass species (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 203.
Abstract: Field observations show that high levels of N and S are required to maintain ryegrass (*Lolium multiflorum*) stands. In this study soft chess (*Bromus mollis*) and ryegrass were grown as monocultures and in 50:50 mixtures in pots in a split-plot randomized complete block arrangement. The main plot was clipped to 2.5 cm height every 14 days versus no clipping. Subplots were two levels of N and six of S. Both species responded to additions of N and S with ryegrass being more responsive. Mathematically calculated competition coefficients showed that in the unclipped pots the two species were competing for the same resources, with ryegrass being the better competitor. The competitive ability of ryegrass increased with the addition of S but was the same for all plus S treatments. In the clipped plots competition coefficients showed that the two species were competing for the same resources in only one of the 12 fertilizer treatments. This result and analysis of N and S uptake data indicate that these two species are competing primarily for light while not competing directly for the two nutrients studied.

4031. Center, D. Michael, and Milton B. Jones. 1983. **Economics of gypsum and elemental sulfur as fertilizers on subclover-grass pastures in northern California.** J. Range Manage. 36(3):378-381.
Abstract: Sulfur deficiencies are widespread on the rangeland soils of California and the application of sulfur-bearing fertilizers has been widely recognized as a promising range improvement on these soils. Considerable work has been done on the management and ecological aspects of sulfur fertilization of California rangeland; however, little or no economic analysis of this improvement exists. Using existing data from subclover-grass pastures in northern California to derive aggregate production functions, optimal application rates of sulfur applied as elemental sulfur and gypsum were determined using

standard marginal analysis. Both elemental sulfur and gypsum proved to be a profitable means of increasing both winter and total yearly production when either harvested hay or grazed forage (AUMs) were considered as products. Using 1981 material costs and product prices applied to total yearly hay production, the optimum rate of sulfur applied as gypsum with 3 years residual was 251 kg/ha for an increased profit of $101 ha/kg/year over unfertilized pastures. The optimum rate of elemental sulfur was 147 kg/ha for a profit increase of $93/ha/yr. When total yearly grazed forage was considered the product, optimum application rates were 195 kg/ha of sulfur as gypsum and 126 kg/ha for elemental sulfur yielding profit increases of $46/ha/yr and $48 ha/yr, respectively. Optimal application rates and profits were lower for both hay production and grazed forage when winter production was optimized.

4032. Center, D. Michael, Milton B. Jones, and Charles E. Vaughn. 1984. **Effects of sulfur and nitrogen levels and clipping on competitive interference between two annual grass species.** Agron. J. 76:65-71.
Abstract: Annual ryegrass (*Lolium multiflorum*) and soft chess (*Bromus mollis*) are often seeded for increased forage production and erosion control on California annual rangelands. Observations in grazed pastures and small plots indicate that the relative proportions of these two species in the community can be influenced by the application of S and N fertilizers. The purpose of this study was to further define the effect of S, N, and clipping on yield response and interference between these two important annual grassland species. Plants were grown in a greenhouse in unleached pots filled with Josephine loam (fine-loamy, mixed mesic Typic Haploxerults). Both species were seeded in monoculture and in a 50:50 mixture at a total density of 2,000 viable seed m^{-2}. Treatments were factorial combinations of 10, 20, 30, 40, or 80 mg S kg^{-1} soil at the time of planting and N applied at 10 or 30 mg kg^{-1} soil every 14 days. One-half of the pots were clipped to a height of 3 cm every 28 days and the other half clipped only at the termination of the experiment. Dry matter yield and percent S were measured for all clippings and percent N for the last clipping on repeatedly clipped pots. Only dry matter production was measured on the pots clipped once at the end of the experiment. Yield and response to S and N of ryegrass was greater than that of brome in all treatments. Yield per plant of ryegrass was greater when grown with brome than in monoculture in both the clipped and unclipped pots. In the clipped pots there was little difference in the yield of brome per plant whether grown in mixture or in monoculture, but under unclipped conditions brome yielded more per plant in monoculture than in mixture. Based on analysis of relative yield totals and relative crowding coefficients no significant competitive interference could be detected in the clipped pots at any S or N level. In the unclipped pots the two species were competing and ryegrass was the better competitor. The nature of the interference was not changed with the addition of S or N. From this it was concluded that at the rates used in this study, the major factor influencing competitive interaction between these two species was light, S and N levels were not major influencing factors.

4033. Center, D. Michael, William A. Williams, and Charles A. Raguse. 1985. **Developing ranch linear programming models using grazing records.** Range Sci. Rep. 1, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 18 pp.
Abstract: Linear programming (LP) is a mathematical decision-making tool that can help ranchers and range managers choose between various management alternatives and to allocate the resources available to them optimally. However, LP has not been extensively used in this way because organizing the data into proper format is a formidable task for a person unfamiliar with the technique. COPLAN, a user-friendly program designed specifically for developing ranch management LP models, has been proven useful on some California ranches, but it is not widely available and can be run only on larger computers. The purpose of this paper is to outline a procedure for using ranch grazing records to develop simple but useful LP models that can be run using widely available generalized LP programs.

4034. Center, D. Michael, Charles E. Vaughn, and Milton B. Jones. 1989. **Effects of management on plant production and nutrient cycling on two annual grassland sites.** Hilgardia 57(1):1-40.
Abstract: Nutrient (nitrogen, phosphorus, sulfur, potassium, and calcium) dynamics and primary productivity were compared in adjacent sheep-grazed and ungrazed and adjacent subclover-seeded and unseeded annual grassland ecosystems. Above-ground and below-ground total plant biomass and nutrient concentrations were measured monthly for two years, and nutrient content of various ecosystem components determined. Nutrient budgets were also developed to compare the effects of the grazing and seeding management practices. Exclusion of sheep grazing had little effect on the system variables we measured. There were only slight differences between the grazed and ungrazed pastures in above-ground and below-ground biomass production and nutrient uptake in either year. There were no substantive between-site differences in nutrient transfers. Subclover growth, accompanied with biennial P and S fertilization, resulted in very large increases in biomass production and much larger flows of all nutrients in both years. The largest nutrient fluxes on all sites were the transfers of mineralized nutrients through the soil available pool to live plants during the growing season. Most of this actively cycling nutrient supply was stored in standing dead material and litter, and was thus retained against leaching between growing seasons. The subsequent fate of these nutrients was then determined by new plant uptake and leaching demands, which showed much annual variation.

4035. Crampton, Beecher. 1964. **Promising range forage and wildland cover crops from University plant introduction nurseries.** Calif. Agric. 18(3):12-13.
Abstract: Increasing interest in wildlands and the pressures exerted on existing range indicate that greater utilization of these areas is possible by introduction of better and more highly productive plants. The University's agronomy department maintains nurseries for evaluating plant species for use on range and wildlands at the Davis campus, Riverside campus, South Coast Field Station, West Side Field Station, and the Hopland Field Station. The Davis nursery is the largest, and promising species are planted at the field stations to determine degrees of adaptation, production, growth characteristics, and disease resistance. Plant materials, largely seeds, are received through the United States Department of Agriculture, from botanical gardens and research stations in the United States, Europe, Asia, North Africa, and from local field collections.

4036. Dahlgren, Randy A., Kenneth W. Tate, David J. Lewis, Edward R. Atwill, John M. Harper, and Barbara H. Allen-Diaz. 2001. **Watershed research examines rangeland management effects on water quality.** Calif. Agric. 55(6):64-71.
Abstract: Oak- and annual grass-dominated rangelands in California occupy 7.4 million acres, often occurring at the state's urban, wildland and agricultural interface. Rapidly changing land uses in these ecosystems have watershed-scale impacts that are the subject of intense debate among policy-makers, environmentalists, and landowners. Watershed research conducted at the Hopland Research and Extension Center between the 1950s and 1980s provided valuable information for predicting the effects of watershed management activities– such as converting oak and chaparral to grasslands– on water quantity and quality, slope stability, and erosion. The research illustrated that conversion from woodland to grassland significantly impacts the hydrology and sediment dynamics of watersheds, suggesting that land-use changes such as vineyards and urban expansion must be evaluated carefully. Preliminary data

from a new series of watershed studies initiated at HREC in 1998 indicate that livestock grazing does not significantly increase nutrient and sediment levels in stream water, but that current fecal coliform standards may be exceeded during storm events.

4037. Demment, Montague W., Milton B. Jones, Ganga P. Deo, D. Michael Center, Martin R. Dally, and William A. Williams. 1987. **Fertilization increases profitability of lamb production on small pastures.** Calif. Agric. 41(1-2):6-8.
Abstract: The goal of the experiment reported here was to determine the effect of P and S fertilization on lamb weight gain and forage quality on small subclover pastures. We applied four treatments to replicated 1-acre pastures: S, P, S & P, and an unfertilized control. Lambs were grazed and their numbers were adjusted each month by adding or removing non-test animals to maintain a constant herbage allowance across treatments. Fertilization of small pastures increased profits in lamb production. While the greatest return on investment was realized with the application alone, we recommend that both S and P be applied together unless knowledge of the soils is detailed. The early weaning and rapid growth in this experiment resulted in spring lambs, which are likely to produce high-grade, low-fat carcasses popular with consumers. Fertilization of the small pastures used in this experiment produced improvements for the following reasons. First, fertilization stimulated plant growth rate while increasing nutrient and decreasing fiber concentrations in the forage. These responses markedly increased the number of lambs that could be supported per acre. Second, our study concentrated the lambs without ewes on pastures, so that a high proportion of the energy harvested by the animals could be converted to gain. Third, small pastures spread evenly the use of the range, prevented the development of patches of mature vegetation, and probably increased the amount of plant production consumed by lambs. Fertilization in this grazing system paid large dividends, increasing production as much as 73% and nearly doubling gross profits.

4038. Demment, Montague, Kevin Rice, Jeff Welker, Milton B. Jones, Mel George, Yu-Bang Lee, and Martin Dally. 1990. **Comparison of controlled rotational and continuous grazing systems in the California annual grassland.** Preliminary Progress Report to Sustainable Agricultural Program, UC - DANR, Univ. Calif. Davis. 13 pp.
Abstract: A comparison of rotational vs. continuous grazing was studied at Hopland using sheep on improved annual rangeland. Grazing system, but not grazing pressure, appears to have had several effects on both animal and plant characteristics in the pastures during the first 2 years of this study. Season-mean individual lamb gain and season-total gain/acre were higher under continuous than under rotational grazing management. Although season-mean individual lamb gain was unaffected by grazing pressure, season-total gain/acre increased at higher grazing pressure. Higher intakes and/or died quality under continuous compared to rotational grazing, and greater carrying capacity under increased grazing pressure, are attributable to lower maturity stage of herbage under these conditions. Lamb performance and ingestive behavior data suggest that compensatory mechanisms may result in apparently similar daily nutrient intakes over a range of grazing pressures. Overall, the continuously grazed pastures appeared to have higher soil water content and higher soil nitrogen levels. Botanical composition and percent nitrogen in plant tissue was unaffected by treatment. Results from the population plots indicate that both demographic (i.e. initial sowing density) and genetic (i.e. cultivar identity) parameters affect subclover population dynamics. Significant block effects could be partially explained by differences among blocks in soil water content over time. Subclover presence appears not to have increased non-clover productivity after one year. This preliminary analysis explores the effects of the experimental design (i.e., treatment) on animal and plant productivity, but does not explain the mechanisms or interactions involved. Early work done on lamb production systems demonstrated the power of regression techniques in detection of controlling factors in these systems when greater than 3 years of data had been collected. Similarly, changes in soil properties were evidence only after several years of treatment. As a result, longer-term study will be necessary for evaluation of the sustainability of clover and lamb production under the various treatments. Thus far, our early results suggest i) no biological or economic advantages of intensive rotational grazing relative to intensive continuous grazing of improved annual grassland by lambs; and ii) a broad range of grazing pressures may be considered in establishing economically optimum stocking rates from year to year.

4039. DiTomaso, Joseph, Kerry Heise, Adina Merenlender, and Gary Kyser. 2001. **A successful burning strategy to control barbed goatgrass.** Oaks 'n' Folks 17(1):3-4.
Abstract: This article describes trials using controlled burning as a tool to control barbed goatgrass, *Aegilops triuncialis*, a noxious annual grass that is spreading throughout California rangelands. In 1997 and 1998, fire was used in two pastures at Hopland R & E Center in efforts to control this weed. At some sites, a single burn reduced goatgrass incidence by about 84%. After two consecutive years of prescribed fire, the weed appeared to be eliminated in one pasture. In general, the incidence of other introduced (non-native) rangeland species was also reduced by burning. By comparison, several native species increased following fire. In summary, prescribed burning, timed before the production of viable seed in barbed goatgrass, can be a very effective control tool. However, unless two consecutive years of controlled burning can be achieved, this weed will not be eliminated.


Milton B. Jones

UC Davis agronomy specialist Ray Evans measures forage height as affected by grazing, May 1957

4040. Evans, Raymond A., and Milton B. Jones. 1958. **Plant height times ground cover versus clipped samples for estimating forage production.** Agron. J. 50:504-506.
Abstract: Two methods of determining forage production were compared using 15 fertilizer trials on annual rangeland of northern California. Clipping the forage was one method; the other consisted of multiplying the average plant height by the average ground cover percentage (HG). This comparison indicated that similar conclusions were reached regarding the effect of fertilizer treatments upon the vegetation when using either of the two methods. On plots with intermediate to mature growth a quantitative relationship, within fairly broad limits, was indicated between clipping and HG values. This was also true of the plots with short vegetation. However, this relationship was not the same in the two groups of plots. In lodged and overmature stands the quantitative relationship was erratic. High variability was encountered with both methods; however, in

comparison to the variation that resulted from effects of treatment this comprised a relatively small portion of the total in plots of these trials. Some advantages of the HG method are: 1) All areas of the plot are sampled in comparison to small clipped samples which may or may not represent the forage production of the plot. Comparison of within-plot variation of yield samples with height measurements and ground cover estimates indicated this relationship. Of course, as the clipped quadrat size or number increases this advantage disappears. 2) Vegetation remains intact so repeated sampling can be made during the growing season on the same plots. The use of small clipped quadrats has a similar advantage. 3) When sampling for botanical composition on plots by the step-point method very little extra time is required to get HG values. Estimates of botanical composition and total forage production can be obtained from one sampling. Some disadvantages are: 1) HG values, although in absolute terms, are not in terms that are customarily used to express forage production (e.g., lbs per acre or animal unit months). 2) When botanical composition is not needed on a plot the HG method requires as much or more time than clipping.

4041. Ewing, Anne L., and John W. Menke. 1983. **Response of soft chess (*Bromus mollis*) and slender oat (*Avena barbata*) to simulated drought cycles.** J. Range Manage. 36(4):415-418.
Abstract: Herbage production in the California annual grassland has been correlated with seasonal weather, particularly fall and spring rainfall patterns. To further examine the relationship between herbage production and rainfall pattern, 3 soil water regimes (-1, -7, -15 bars) simulating expected rainfall and drought events in annual rangelands were applied in seminatural annual grassland communities. Soft chess (*Bromus mollis*) tillers grew longest under the -7 bar water regime treatments while total plant growth was greatest under the -1 bar treatment. Tiller length and total growth of slender oat (*Avena barbata*) were greatest under the -1 bar treatment. Vegetative growth of slender oat was less sensitive to season-long water regimes than soft chess. The two species required different soil water conditions for maximum spring growth; soft chess put on spring growth most rapidly in the -7 bar treatment while slender oat grew fastest in the -1 bar treatment. Periodic water stress during the growing season did not reduce spring herbage production. Maximum growth and herbage production occurred only when soil water was available after March 15. Withholding water after March 15 reduced herbage production by 46%.

4042. George, Melvin R., and Milton B. Jones. 1985. **Fertilization of nonseeded annual grassland.** Range Sci. Rep. 2, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 4 pp.
Abstract: Annual grassland soils without legumes are nitrogen deficient. To increase winter forage and total production, nitrogen must be added by a legume or nitrogen fertilization. Phosphorus and sulfur deficiencies are quite common. Deficiencies of potassium, boron, and lime occur on acid soils but are not widespread. In some areas, molybdenum deficiencies are quite common. Usually these latter deficiencies become evident only after adequate amounts of P and S have been applied on legume pastures. This publication describes nitrogen fertilization of annual grassland that does not contain a significant natural or seeded legume component. Ammonium sulfate (21-0-0), ammonium phosphate (16-20-0), and urea (40-0-0) are most frequently applied on annual rangeland. Soil and plant tissue testing can help answer what nutrients to apply in addition to nitrogen. In the 12- to 30-inch rainfall zone, nitrogen is generally applied in the fall to lengthen the green feed period by increasing winter growth. Generally a good forage response is gained from applying between 40 and 80 lb/acre of nitrogen. Traditionally, nitrogen applications have been made in the fall near the time of the first fall rains. In regions of high rainfall and where heavy winter grazing has occurred, spring applications of nitrogen may be beneficial. Fertilizer can be applied from the ground, or in rough/rocky ranges, by aircraft. Yearly application of nitrogen generally increases the percentage of grasses and forbs. The particular grasses which will increase depend upon the grazing or clipping management of the pasture in question.

4043. George, Melvin R., Kent D. Olson, and John W. Menke. 1988. **Range weather: a comparison at three California range research stations.** Calif. Agric. 42(1):30-32.
Abstract: Computerized analysis of weather affecting seasonal forage growth can be useful to livestock producers. Knowing when to expect the first rain in the fall and the length of winter can reduce risk in livestock operations. This report illustrates the use of weather analysis as a tool for determining expected timing of weather and plant growth events. Such analyses can be used to assess risk. Weather data was collected from San Joaquin Experimental Range Station, Hopland Field Station, and Sierra Foothill Field Station. Data used was from 51, 31, and 23 years, respectively.

4044. George, Melvin R., Charles A. Raguse, W. James Clawson, Charles B. Wilson, Robert L. Willoughby, Neil K. McDougald, Don A. Duncan, and Alfred H. Murphy. 1988. **Correlation of degree-days with annual herbage yields and livestock gains.** J. Range Manage. 41(3):193-197.
Abstract: On California's winter annual rangelands, precipitation controls the beginning and the end of the growing season while temperature largely controls seasonal growth rates within the growing season. Post-germination accumulated degree-days (ADD) account for the length of the growing season and variation of daily temperature. Simple correlations of ADD and herbage yield or resultant livestock gains were determined at 5 locations in annual type range in northern California. Degree-day values were determined by summing daily degree-days from the beginning of the growing season after germinating rainfall until the clipping or weigh dates. Accumulated degree-days accounted for 74% to 91% of the variation in seasonal herbage yield while accumulated days (AD) accounted for 64% to 86% of the variation. Together, ADD and AD accounted for 94% to 86% respectively, of the variation in stocker cattle weights. Regression coefficients relating ADD to herbage yield appear to predict maximum site productivity. A procedure for estimating a seasonal herbage yield profile based on key growth curve inflection points and using simple field observations with three clipping dates and ADD is proposed.

4045. George, Melvin R., William A. Williams, Neil K. McDougald, W. James Clawson, and Alfred H. Murphy. 1989. **Predicting peak standing crop on annual range using weather variables.** J. Range Manage. 42(6):508-513.
Abstract: Wide yearly fluctuations in peak standing crop on California annual-type range are largely explained by temperature and precipitation patterns. The objective of this study is to improve the predictability of functions relating weather patterns and peak standing crop by including degree-days, dry periods, evaporation, season start dates, and lengths of precipitation as independent variables. Peak standing crop was regressed on these independent variables for the University of California Hopland Field Station (HFS) and San Joaquin Experimental Range (SJER). Fall and winter precipitation, winter degree days, and longest winter dry period were related to peak standing crop at HFS (R^2= 0.61). Spring precipitation, growing season degree days, winter evaporation, and winter and spring start dates were related to peak standing crop at SJER (R^2= .72). The relationship of peak standing crop to accumulated precipitation on November 20 using 33 years of data (r^2= 0.34) was weaker than previously reported for the first 16 years (r^2= 0.49). This study suggests that timely prediction of peak standing crop may be possible at HFS but more difficult at SJER.

4046. George, Melvin R., Joel R. Brown, and W. James Clawson.

1992. **Application of nonequilibrium ecology to management of Mediterranean grasslands.** J. Range Manage. 45:436-440.
Abstract: The state and transition model and the ball and cup analogy are used to organize the vegetation dynamics knowledge base for California's annual-dominated Mediterranean grasslands. These models help identify irreversible transitions and alternate stable states. Mechanisms that facilitate movement between successional stable states are categorized as demographic inertia, seedbank and germination, grazing impacts, establishment and competition, fire feedback, and irreversible changes in soil conditions. While theoretical work needs to continue to further describe states and transitions, managers can begin to use existing knowledge to develop management plans with realistic species composition objectives and to select the appropriate tools for reaching objectives.


A. H. Murphy
Sheep graze on a steep slope in Watershed I, Spring 1976

4047. George, Mel, William Frost, Neil McDougald, J. Michael Connor, James Bartolome, Richard Standiford, John Maas, and Robert Timm. 1996. **Ch. 5: Livestock and grazing management.** Pp. 51-67 *in:* R. Standiford (tech. coord.), Guidelines for Managing California's Hardwood Rangelands, UC DANR Publ. 3368. UC Integrated Hardwood Range Management Program, Univ. Calif. Berkeley.
Abstract: Livestock grazing is a dominant land use on California's hardwood rangelands. This chapter provides guidelines regarding use of oak hardwoods as grazing lands, involving principles of agronomy, plant ecology, animal nutrition, animal health, and predator management. The emphasis is on cattle production, and included are topics such as forage productivity and availability, grazing management, animal health issues, and identification and management of predator damage.

4048. George, Mel, Jim Bartolome, Neil McDougald, Mike Connor, Charles Vaughn, and Gary Markegard. 2001. **Annual range forage production.** Rangeland Management Series, Publ. 8018, Div. Agric. & Nat. Resour., Univ. Calif. 9 pp.
Abstract: California's foothill rangelands make up the primary forage source for the state's livestock industry. Forage productivity in these annual rangelands varies greatly from season to season and from year to year. Analysis of long-term forage production data from the Hopland R & E Center, Sierra Foothill R & E Center, and the San Joaquin Experimental Range has allowed researchers to describe seasonal and annual variation of this forage resource. The data in this publication are intended to help range managers identify potential forage gaps, fine-tune grazing plans, and develop contingency plans for drought. Four factors– precipitation, temperature, soil characteristics, and plant residue– largely control forage productivity and seasonal species composition. These factors are discussed, and site-related influences are described. Forage productivity data from Hopland, Sierra Foothill, and San Joaquin experimental sites is compared and contrasted. It is concluded that while rainfall determines the beginning and end of the growing season, temperature usually determines the rate of forage productivity during the growing season. Range managers cannot control the weather, but they can influence forage productivity and species composition by managing grazing to leave adequate residual dry matter. During winter periods of slow forage growth, forage quantity and quality often are inadequate to support cattle weight gains. Forage quality and animal performance both decline rapidly as forage matures and dries following the depletion of soil moisture and the onset of the dry season. The frequency of poor forage season and years can be estimated from long-term data sets and can then be used to assess risk and develop drought contingency plans.

4049. Giusti, Gregory A. 2001. **Oak woodlands of Mendocino County: an assessment of their distribution, ownership patterns and policies and projects affecting their conservation.** UC Integrated Hardwood Range Management Program, Ukiah, CA. 66 pp.
Abstract: This publication is a report of the Oak Conservation Committee, a collaborative effort between the County of Mendocino and the UC Integrated Hardwood Range Management Program (IHRMP). The Committee was charged with addressing the directive provided to counties by the Board of Forestry in 1993 to develop locally based conservation strategies. The following Phases comprise the Committee's work and are detailed in this report: I) An assessment of current status of oak woodlands in Mendocino County; II) An assessment of current programs and activities focusing on oak woodland conservation in Mendocino County; III) An assessment of oak resources at risk; IV) A comprehensive evaluation of current programs and future needs; and V) Final report of the Committee's efforts. Educational, research, and extension activities related to oak management and conversation described in this publication include past and current efforts of the Hopland R & E Center, including IHRMP staff at this location.

4050. Graves, Walter L. 1986. **Screening Mediterranean indigenous annual and perennial legume germplasm for range and pasture improvement in California and Baja California, Mexico.** Pp. 39-45 *in:* Beef and Range Workgroup Report, Cooperative Extension, Univ. Calif.
Abstract: This report introduces a cooperative, international effort to test diverse varieties of legumes for their potential adaptation to rangelands in California and Baja California. Objective of these trials include screening and testing of both legume varieties (particularly cultivars of subclover) and associated *Rhizobium* bacteria to determine their potential for improving rangeland production in basic pH soils in arid areas of California; evaluate these materials for improved frost- and cold-tolerance adaptations; evaluate resistance to alfalfa weevils; develop international exchanges for plant materials; and encourage seed production and industry use of superior plant materials. Data from field tests at Hopland Field Station regarding first-year establishment and beginning third-year hardseededness are reported, as are data from a cooperator's plots in Mexico. During the fall of 1985, some 30 cooperators implemented more than 40 field trials of over 100 experimental and standard commercial strains of legumes. Further results will be forthcoming.

4051. Graves, Walter L. 1987. **Screening Mediterranean indigenous annual and perennial legume germplasm for range and pasture improvement in California and Baja California, Mexico.** Pp. 24-31 *in:* Beef and Range Workgroup Report, Cooperative Extension, Univ. Calif.
Abstract: This report summarizes research results from a

cooperative, international efforts to test diverse varieties of legumes for their potential adaptation to rangelands in California and Baja California. Objective of these trials include screening and testing of both legume varieties and associated *Rhizobium* bacteria to determine their potential for improving rangeland production in basic pH soils in arid areas of California; evaluate these materials for improved frost- and cold-tolerance adaptations; evaluate resistance to alfalfa weevils; develop international exchanges for plant materials; and encourage seed production and industry use of superior plant materials. Data from field tests at various locations are reportedand include results from varieties of *Medicago* spp. and *Trifolium* spp.

4052. Graves, Walter L., Burgess L. Kay, Milton B. Jones, and W. M. Jarrell. 1987. **Annual legume germplasm exploration and testing to improve range, pasture and soils in the winter rainfall California climate.** Pp. 188-191 *in:* Proc. Symp. Weed and Seedbed Ecol. of Rangeland Plants, G. W. Fraiser and R. A. Evans (eds.), USDA Agric. Res. Stn., Tucson, AZ, Apr. 21-23.
Abstract: Six years of plant exploration and testing of subclover (*Trifolium subterraneum*) and their associated nitrogen-fixing *Rhizobium* bacteria has identified encouraging candidates for California and Baja California in Mexico. Selection and adaptation experiments are discussed. Plant establishment and management of promising subclover strains are highlighted.

4053. Graves, Walter L., Burgess L. Kay, Milton B. Jones, W. M. Jarrell, and J. C. Burton. 1987. **Potential use of annual legumes in a winter-rainfall, California-type climate for a cereal-ley farming system.** P. 111 *in:* The Role of Legumes in Conservation Tillage Systems, J. F. Power (ed.), Univ. of Georgia, Athens, GA. Soil Conservation Soc. of America.
Abstract: Several million California acres are dry farmed to cereals each year during the winter and spring rainy season. This demands a large amount of fossil fuel energy for N fertilizer and machinery. Introducing a ley-farming system with specific lines of annual legumes would considerably reduce these nonrenewable energy inputs. The ability to carry over viable seed through the cereal cropping phase is essential to a ley-farming system. This paper reports on efforts underway to collect and evaluate various types of legumes' (subclover and medics) germplasm from the Mediterranean region applicable to California climate that might be suitable to a cereal/annual legume rotation system. Subclover germplasm has proven more adaptable to the wide range of neutral and alkaline soils in California. Initial testing at Hopland demonstrated that hardseeded differences began to show at the beginning of the third growing season. Several promising strains have been identified and there will be further screening trials. The next step is to test the most promising hardseededness annual legume lines in an actual ley-farming situation. The lines will be evaluated on their regeneration ability under a periodic cereal cropping system. The integration of livestock (sheep and/or cattle) will be necessary to optimize land use, grain and meat/fiber outputs, and N cycling.

4054. Graves, Walter L., Milton B. Jones, and Burgess L. Kay. 1988. **Hardseeded subclover strains enhance long-term pasture in northern California (Abstract).** P. 127 *in:* Agron. Abstr., Am. Soc. Agron., Anaheim, CA, Nov. 27 - Dec. 2.
Abstract: Hardseededness is considered an important factor governing long-term persistence in a winter rainfall Mediterranean type climate range/pasture system. The objectives of this trial were to measure long term persistence and adaptation of 16 known hardseeded subclover (*Trifolium subterraneum*) strains from the Mediterranean and Australian naturalized subclover regions and to compare these strains to presently used and other new cultivars for pasture improvement in northern California. After subjecting the trial to a simulated drought cycle before flower initiation during the early spring of the third growing cycle, the stand rating during the spring of the 5th growing cycle (year) identified several promising candidates that demonstrate improvement and superiority for regeneration over presently used and other new cultivars for range/pasture improvement. Thirteen of the 16 hardseeded strains demonstrated regeneration ability superior to Enfield, a new Australian cultivar, and 10 of these 16 strains were equal to or better than the Australian cultivar, Woogenellup.

4055. Graves, Walter L., Milton B. Jones, and Burgess L. Kay. 1989. **Evaluations of subclover strain factors that contribute to long-term pasture regeneration in Northern California (Abstract).** P. 83 *in:* Agron. Abstr., Am. Soc. Agron., Las Vegas, NV, Oct. 15-20.
Abstract: A number of factors play a role in subclover pasture establishment, adaptation, and regeneration in the northern California Mediterranean type winter rainfall region. High seed production and hardseededness are considered key traits for regeneration and long-term persistence where drought cycle and rainfall variability in this region can cause pasture stand failures. Exploration for subclover strains with these traits, their introduction and establishment provide the setting for this ongoing six seasons long-term trial. Residual seed production and hardseededness evaluation provide insight into subclover strain introductions superiority over presently used and other new Australian cultivars. The implementation of these results will be discussed in the context of plant establishment and management recommendations.

Al Murphy examines legume varieties at Vassar Corner, 1968

4056. Graves, Walter L., William A. Williams, Charles E. Vaughn, Craig D. Thomsen, and Milton B. Jones. 2001. **Australian varieties improve pasture in long-term annual legume trials.** Calif. Agric. 55(6):60-63.
Abstract: More than 50 Australian legume varieties for rangeland have been introduced commercially since the mid-1980s, but none of them had been tested for their adaptability to California. To determine their viability, in 1990 we planted a number of these varieties at the Hopland Research and Extension Center, along with some that were already popular in California. We evaluated them over the course of 10 years, and in 1997 planted 16 more varieties that had been subsequently introduced. Many of the cultivars planted in 1990 persisted to cover more than 50% of the plots, while others covered a smaller portion and several disappeared completely. Our evaluation shows which of the new cultivars are likely to improve rangeland in Northern California coastal areas. The soil and climate of the Hopland site are representative of many in the north coast range of California. Based on our study, we recommend that annual legume seed mixes for dryland pasture improvements in this region

include the commercially available, imported subclover varieties Wollgenellup, Karridale, Junee, Leura, Gosse, Denmark, Dalkeith, and Losa and the rose clovers Hykon, Wilton, and Monte Frio. We also suggest fertilizing at the rates used in this study, i.e., application of single-superphosphate fertilizer (0-20-0-12) at a rate of 500 lbs/acre followed by light disking to prepare the seedbed for planting.

4057. Gregg, P. E. H., Milton B. Jones, and V. V. Rendig. 1980. **Diagnosis of sulfur deficiencies in California rangeland (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 167.
Abstract: Data from a past field trial, which investigated S deficiency indices in subclover were reexamined to determine whether the SO_4-S:total S ratio was a more sensitive indicator than SO_4-S, total S or N:S ratio. R^2 values, from negative exponential curves, were 0.75 and 0.71 for SO_4-S and SO_4-S:total S ratio respectively. Very low correlation coefficients were found for total S and N:S ratio. Five current field trials, which included S treatments, were used to further evaluate the utility of the SO_4-S:total S ratio. On the basis of percent relative yield response to S fertilizer, R^2 values for SO_4-S and the SO_4-S:total S ratio in subclover, at final harvest, were similar (0.60). Critical values for SO_4-S and SO_4-S:total S ratio at 90% maximum relative yield were 119 ppm and 0.10 respectively. To predict relative yield from S indices in subclover at a spring harvest, $S0_4$-S was clearly superior. A field test for determining low medium and high amounts of $S0_4$-S in subclover was developed, using a colorimetric technique which measures SO_4-S concentration in plant sap.

4058. Hatch, Daphne, James W. Bartolome, and Deborah Hillyard. 1991. **Testing a management strategy for restoration of California's native grasslands.** Pp. 343-349 *in:* Proc. Symp., Nat. Areas and Yosemite: Prospects for the Future. Nat. Park Service.
Abstract: California's grasslands were drastically altered by the invasion of Mediterranean weeds following European immigration. Pristine grasslands were believed to be perennial bunchgrass prairies with purple needlegrass (*Stipa pulchra*) as a major component. In developing a restoration strategy for sites with remnant populations of *Stipa pulchra* we address two interrelated problems: 1) how to increase *Stipa* populations, 2) how to reduce competition with, and usurp the space occupied by, exotic annuals. Based on previous research results, we hypothesized that populations of *Stipa pulchra* would increase more rapidly in density and/or cover when managed under a combination of winter and summer seasonal livestock grazing and all burning than through complete protection from grazing. A replicated randomized complete block experiment with two main effects, burning (after fall germination or unburned) and grazing (winter and summer or ungrazed), was conducted in two locations. This paper considers conceptualization of the experiment and 1989-90 pre- and post-burn *Stipa pulchra* seedling recruitment at Hopland and Sierra Field Stations. Within-treatment comparisons show significant increases in numbers of *Stipa* seedlings in 1990 in the grazed/unburned, ungrazed/burned, and grazed/burned treatments at Sierra, with no increase in seedling numbers in the ungrazed / unburned plots. There was no significant increase in seedling recruitment within any treatment combination at Hopland. Sierra has received near average rainfall while Hopland has experienced six years of drought.

4059. Heady, Harold F. 1954. **Viable seed recovered from fecal pellets of sheep and deer.** J. Range Manage. 7(6):259-261.
Abstract: This study investigated the viability and diversity of seed after passage through the digestive systems of sheep and deer. Fecal pellets were collected from 24 sheep and 34 deer at Hopland; seeds from these fecal samples were germinated in the laboratory and greenhouse. Inconsistencies in seed diversity from one individual animal to another were striking; one animal had numerous viable seeds in fecal pellets, while another had none. Rumen contents were different for animals collected at the same time. Seeds in the rumen vs. the fecal pellets were almost totally different. Sheep and deer gave different results. In view of the wide variations found, the sample seems small to draw detailed conclusions. However, the following general conclusions are offered: Sheep and deer consume the foliage and seeds of many plants in amounts varying by individual preferences, season, availability, and probably other reasons. A portion of the seeds consumed pass through these animals in viable condition; the portion is dependent on the nature of the seed and the characteristics of the animal, and is impossible to predict for uncontrolled animals on native ranges. Sheep and deer have contributed to the spread of plants introduced onto California ranges. Sheep, in particular, and deer may carry seeds of noxious plants to cultivated fields and possibly could be utilized to spread desirable forage species.

Guy E. Connolly

Ag technicians Marshall Slater (left) and Harold Smith (right) repair fence in headquarters area, January 1975

4060. Heady, Harold F. 1956. **Changes in a California annual plant community induced by manipulation of natural mulch.** Ecology 37(4):798-812.
Abstract: Amount and position of natural mulch were manipulated immediately before fall rains in an experiment on the California annual range at Hopland with 8 treatments and 8 replications for 4 years. A total of 46 species was found in the study area; 16 were alien and 40 were annual. Six species that were both alien and annual contributed between 67% and 84% of the composition. A perennial bunchgrass, *Stipa pulchra*, increased in numbers from 0 to 612 plants within the livestock exclosure between 1952 and 1955. Amounts of mulch in the different treatments varied between 0 and nearly 5,000 lbs/acre. Not all of the mulch decomposed each year, so there was a gradual accumulation. With increasing amounts of mulch, there was a highly significant increase in herbage production the following spring. *Baeria chrysostoma* and *Aira caryophyllea* were abundant with no mulch, *Bromus mollis* with the largest amounts, and legumes and several grasses with intermediate amounts. *Erodium botrys* responded more to variations in yearly weather than to mulch treatment. The height of the stubble (position of mulch) seemed to determine the height reached by *Bromus mollis* during the fall growing period.

4061. Heady, Harold F. 1957. **Effect of cages on yield and composition in the California annual type.** J. Range Manage. 10(4):175-177.
Abstract: This study was undertaken to determine the effect of cages on herbage yield when used to protect small plots of vegetation from livestock use. Studies by others indicate that the change in microclimate under the cages results in an increase in plant growth. Results of this study are in agreement with the reported findings under conditions of slow growth in the winter period. With the onset

of warm spring temperatures and rapid growth of plants, the differences soon disappear, and by plant maturity any effects of the cage on amount of growth, percentage botanical composition, and foliage cover could not be detected in the conditions of this experiment. The conclusion is reached that the cages, themselves, do not materially influence results of total yield studies and utilization in the area of the experiment. Yields taken in late winter with cage techniques will include a significant cage effect. These results should apply to most of the California annual-grass type, although the point has not been tested at other locations.

4062. Heady, Harold F. 1958. **Vegetational changes in the California annual type.** Ecology 39(3):402-416.
Abstract: Changes in vegetation were studied at 3 sites for 5 growing seasons. Number of species on 2,400 quadrants one inch square constituted the data. Growth pattern from germination in November to termination of growth in June was observed. Average number of plants per square inch varied between 3.3 and 35.0. All species decreased in numbers per unit area from December to June but *Bromus mollis*, *B. rigidus*, and *Erodium botrys* decreased less than others thus increased in percentage species composition. Number of plants and species varied greatly between years. Changes due to grazing, seeding, fertilization and fire were reviewed and the influence of mulch on percentage botanical composition is illustrated.

4063. Heady, Harold F., and Donald T. Torell. 1959. **Forage preference exhibited by sheep with esophageal fistulas.** J. Range Manage. 12(1):28-34.
Abstract: Sheep with esophageal fistulas were used to determine the percentage of botanical composition of consumed forage. The forage presented to the animals was sampled by points in the field, point with a microscope on clipped plants, and by weight. The fistula-collected material was sampled with the microscope technique. Samples were taken with 3 animals and with the field methods on 4 plots of different botanical composition during the growing season of 1957. The forage presented to the sheep was principally soft chess, filaree, and bur clover. The percentage of grass was least by the weight method, slightly more by the points, and considerably more by the laboratory points. The proportion by different methods showed similar trends between plots for the primary species. Therefore, the methods sampled the trends in adequate manner, even though the absolute values were different between techniques. Animals showed high preference for bur clover leaves in May and for seed in July. Bur clover was avoided during the winter. They selected filaree in July in a much higher ratio than it was present in the forage. Where a species was high in composition, they tended to take more of it. Preference was not related to height of the plant materials. Much variability existed between sheep in the preference for plant species on a short time basis, but over the whole season very little difference appeared in the diets of different animals. Preference for bur clover seed in the summer is frequently given as the reason that animals maintain condition on dry annual ranges. This study indicates that the seed of filaree is also an important element in sustaining animal condition into the dry season.

4064. Heady, Harold F. 1961. **Continuous vs. specialized grazing systems: a review and application to the California annual type.** J. Range Manage. 14(4):182-193.
Abstract: The results of experimentation with grazing systems, such as continuous and the more specialized systems (rotation and deferred-rotation), are reviewed. None of these experiments have been comparable because they have employed different combinations of grazing and rest periods; they have been conducted on different types of vegetation; and they have used different kinds of combinations of animals. An evaluation of this experimentation indicates two major conclusions. One is that a specialized grazing system has no advantage in livestock production over continuous grazing, at least with good or excellent ranges under comparable stocking rates and degree of care of other management practices. The second is that other management factors are more important in the production of livestock than of system grazing. Evidence in support of these conclusions has been reviewed in the paper. Yearlong grazing at reasonable stocking rates is the best way to manage the California annual type because it pays primary attention to the day by day animal needs and because yearlong grazing amounts to a partial deferment every year. Enough forage must remain at the end of the forage growth period so that the animals have ample feed to last them until the new crop is produced several months later. This amounts to a very light grazing on all the range during the growing season every year.

4065. Heady, Harold F. 1965. **The influence of mulch on herbage production in an annual grassland.** Pp. 391-394 *in:* Proc. IX Int. Grassland Congr., Brazil.
Abstract: Varying amounts of herbaceous material left on the soil at the end of the dry season as mulch for an eight-year period resulted in a range of average herbage production from 1,000 to 2,300 pounds per acre. Extensive changes in species composition also developed in this natural Mediterranean-type annual grassland. These changes occurred within a 3-year period. Differences in bulk density and soil structure of the 0-3 inch layer developed more slowly and were correlated with vegetational changes. Content of nitrogen and phosphorus in the soil were not significantly different between treatments after 8 years. The results suggest that the rancher can partially control forage production by degree of forage utilization, that responses to changes to grazing pressure occur rapidly, and that short periods of overgrazing do not permanently damage the soil.

4066. Heady, Harold F., and George M. VanDyne. 1965. **Prediction of weight composition from point samples on clipped herbage.** J. Range Manage. 18(3):144-148.
Abstract: Regression analyses show that percentage botanical composition by weight can be estimated from composition determined with the laboratory point method. This conclusion is based on point sampling with a binocular microscope of clipped herbage and hand separation of the same material. Satisfactory results were obtained by analysis of the percentage data, on a linear basis through the origin without transformation of the variates. Individual grass species exhibited percentage weight to percentage point ratios at maturity from 0.17 to 0.79 and forbs from 1.00 to 1.99. Prediction equations for all grasses combined and all forbs combined were similar to the equations for the dominant species of each group at each sampling period. Ratios of weight to points changed during the growing season because of changing thickness of plant parts, shattering, and varying proportions of plant parts. With maturity, forbs became heavier and grasses lighter per point, whether measured in the field or laboratory. In the field grasses increased while forbs decreased in herbage cover and grasses increased in height more than forbs. Weight to height ratios decreased in both forbs and grasses but more so in the grasses. Regression of percent weight on percent points varied with species composition, although not as much as among species and through the growing season. Percentage weight composition can be estimated satisfactorily from laboratory point analysis, if differences among species, seasons of growth, and botanical composition are taken into account.

4067. Heady, Harold F., and Michael D. Pitt. 1979. **Reactions of northern California grass-woodland to vegetational type conversions.** Hilgardia 47(3):51-73.
Abstract: Changes in standing crop, cover, and percent botanical composition of annual vegetation as influenced by microsite and type conversion were investigated on an 86.2-hectare watershed at the Hopland Field Station. Type conversion from woody vegetation to grassland tripled total standing crop of herbaceous plants on the

watershed, with much of this increase occurring on sites formerly supporting a dense and semi-dense woodland overstory. However, the sites that were originally woodland never produced as much forage as those that were originally open grassland. The managerial problem of seasonally adjusting stocking rates in response to changing forage production occurred at the end of the growing season. Short annual plants such as nitgrass, silver hairgrass, rattlesnake weed, filaree, bur-clover, and true clovers, attained their greatest percent botanical composition on the historically open grassland sites. Type conversion produced increases in botanical composition primarily for those taller annual and perennial plant species capable of colonizing the formerly dense woodland sites mainly occurring on north-facing slopes. These plant species included wild oats, ripgut, vetches, and Italian thistle. In the sheep grazing system employed, adding animal units to utilize increased spring forage following brush conversion required alternative sources of feed during other periods of the year.

4068. Heady, Harold F., and Michael D. Pitt. 1979. **Seasonal versus continuous grazing on annual vegetation of northern California.** Calif. Rangelands 1(6):231-232.
Abstract: Continuous and repeated seasonal grazing produced similar patterns in foliage cover, standing crop, and botanical composition measured in ungrazed vegetation at the end of each growing season. June cover in those pastures grazed on a repeated seasonal basis showed the same yearly differences as cover in the pasture grazed continuously. Total standing crop in June also responded similarly to both kinds of grazing treatments over the three year period.

4069. Heady, Harold F., James W. Bartolome, M. D. Pitt, G. D. Savelle, and M. C. Stroud. 1991. **Ch. 16. California grassland.** Pp. 313-335 *in:* R. T. Coupland (ed.), Ecosystems of the World, Vol. 8A: Natural Grasslands – Introduction and Western Hemisphere. Elsevier, London.
Abstract: California's Mediterranean grassland forms a diverse yet distinctive vegetational type. The plant species now dominant are mostly introduced annuals which have replaced the pristine perennial bunchgrass vegetation. The exotic annual species are adapted to both the climate, characterized by recurrent years of drought and heavy grazing. Species composition and productivity vary enormously both temporally and spatially. Phenological development also varies according to site, species, and weather. However, the annual plants germinate, reproduce, and die within a 6- to 8-month period. This means that all nutrient cycling through the annual plants are returned to the environment each year. A number of managerial practices are utilized by graziers in an attempt to deal with fluctuations in productivity. These have included fire, different grazing systems, seeding perennial grasses and/or annual legumes, fertilization, and a number of other practices. However, mulch manipulation has proven the most important factor under the range manager's control.

4070. Holmes, Tyson H. 1995. **Woodland canopy structure and the light response of juvenile *Quercus lobata* (Fagaceae).** Am. J. Bot. 82(11):1432-1442.
Abstract: I investigated competition for light between canopy plants and juvenile valley oaks (*Quercus lobata*) in a mixed broadleaf woodland of California's northern Coast Ranges. Canopy effects on understory light supply were separated among the overlying adult valley oak, the adult's woody understory, and neighboring trees and shrubs through a series of light sampling surveys and measurements of the number, size, and spatial distribution of neighboring plants. Light supply in the understory was primarily influenced by neighboring plants, with no detectable effect of the overlying adult valley oak. Light supply in the understory averaged 25% full sun due to a high frequency of canopy gaps and a typically open understory. Seedling response to understory light supply was investigated in an experimental sunfleck gradient (10%, 19%, and 100% full sun). Between 10% and 100% full sun, seedling growth increased by 90% and the shoot:root ratio changed from 1.561 to 0.607. Shade seedlings were also taller and produced fewer, larger, and thinner leaves than seedlings grown in full sun. A field survey of the spatial distribution and crown morphology of saplings and young adults found 1) the distance between young valley oaks and neighboring overstory trees to increase with neighbor size, and 2) crowns of the young oaks to be skewed away from neighbors. Although shading by the canopy was only moderate, canopy effects on understory light supply may restrict juvenile recruitment of valley oak in this woodland.

4071. Hooper, Jack F., and Harold F. Heady. 1970. **An economic analysis of optimum rates of grazing in the California annual-type grassland.** J. Range Manage. 23(5):307-311.
Abstract: In the early days of the West, marketing practices, associated with low-cost grazing and lack of knowledge about range management, led to heavy and sometimes destructive utilization of range vegetation. As the field of range science developed, control of grazing to achieve "moderate" utilization became an important management tool. However, too little attention has been given to the economics of "moderate use" recommendations. This study indicates the optimum rate of utilization on a Sutherlin soil in the annual-type grassland of California leaves approximately 500 lb/acre of plant residue. Examination of opportunity costs indicates the economic loss for heavy grazing is several times that of light use. Thus, range managers who recommend "moderate" or even "light" grazing are in effect advocating a small loss (opportunity cost of light grazing) as insurance against a larger loss (opportunity cost of heavy grazing).

Jeff Lee, SR Press Democrat

Al Murphy with range brush disk used in vegetative conversion of chaparral, James III Pasture, October 1971

4072. Jones, Milton B., Alfred H. Murphy, Donald T. Torell, William C. Weir, and R. Merton Love. 1957. **Improved pastures: both sheep production and forage yield increased by range improvement.** Calif. Agric. 11(5):12-13.
Abstract: Increase in growth of forage and in pounds of lamb produced per acre was achieved by use of nitrogen and phosphorus fertilizers and introduced range plants, including hardinggrass, annual clovers, and alfalfa. In the low feed production period, January and February, the improved pastures yielded about 3½ times as much forage as untreated native range. Ewes with lambs were maintained in better condition and lambs gained slightly faster during early winter months on improved range compared to native pastures. By the end of May the average lamb weight was the same for both

groups. The pasture treatment resulted in an increase of 141 sheep days per acre for the 5-month period ending May 28.

4073. Jones, Milton B., and Raymond A. Evans. 1959. **Modification of the step-point method for evaluating species yield changes in fertilizer trials on annual grasslands.** Agron. J. 51:467-470.
Abstract: Two methods of determining forage production of species on fertilizer plots in annual grasslands in California were compared. Clipping the forage, separating it into the groups (grasses, broadleaf filaree, and clovers), oven-drying and weighing constituted one method; the other consisted of multiplying the average species height by the percentage of the ground covered by that species (H_xG). The 2 methods were evaluated in 8 comparisons consisting of 432 plots. In each instance the correlation coefficient was significant at the 1% level. The regression coefficients of broadleaf filaree were homogeneous, but those of the grasses and clovers were heterogeneous. Fewer significant differences were noted in species yield data as compared to H_xG data of the same plots. High variability in the yield data where one square foot per plot was clipped accounted for these differences. Weights of separated material from three square feet per plot were comparable to H_xG values in terms of significant differences between treatments, and between-plot variation, but the within-plot variation was much greater for the clipped plots than for H_xG. The time required to obtain botanical composition data by the H_xG method was about ¼ that for clipping and separating the species on 3 square feet per plot.

4074. Jones, Milton B. 1960. **Responses of annual range to urea applied at various dates.** J. Range Manage. 13(4):188-192.
Abstract: During one wet year and two dry years urea was applied to different annual range plots on 6 dates over a 7-month period from September to March. Applying urea early in the fall was generally more effective in producing winter feed than late fall applications, but for production of spring feed the date of application made no consistent difference except that March application was too late to produce maximum yields. At the February sampling date, plots fertilized with urea the previous September, November, December, and January yielded forage with a progressively higher nitrogen content as the date of application advanced. At the May sampling date, the month of urea application produced no significant difference in nitrogen content of the forage except that plots fertilized in March produced forage in May with the highest nitrogen content. Total nitrogen uptake was increased by urea fertilization but the date of application produced no significant difference at the February sampling. At the May sampling date, application of urea in February of the two driest years resulted in the greatest yield of nitrogen per acre. During the wet year there was no significant difference in pounds of nitrogen produced as affected by date of application.

4075. Jones, Milton B., and Raymond A. Evans. 1960. **Botanical composition changes in annual grassland as affected by fertilization and grazing.** Agron. J. 52:459-461.
Abstract: Changes in botanical composition resulting from applications of nitrogen and phosphorus, with and without sheep grazing, on the annual range type of California were studied at two locations. The first site was unimproved resident-range ad the second had been seeded to sub, rose, and crimson clovers, hardinggrass, and soft chess. The percentage of soft chess at the resident-range location was increased by nitrogen fertilization on grazed plots for 2 of 3 years but increased only the first year on ungrazed plots. Percentage of soft chess on the reseeded-range area was increased both years by nitrogen fertilization when grazed but decreased when protected. The percentage of ripgut on the resident-range site was increased by phosphorus fertilization, and this increase was less on grazed plots than on ungrazed. On the seeded site, where available phosphorus was adequate, ripgut was increased by nitrogen fertilization. Grazing reduced the percentage of ripgut at both locations. Slender wild oats and broadleaf filaree, which were major components of the forage at the resident-range site only, were particularly responsive to nitrogen and both decreased in abundance when grazed. Little fertilizer effect could be measured in filaree on grazed plots. In general, clovers were decreased by nitrogen fertilization, but subclover appeared to be an exception in 1958. Phosphorus increased the clovers. The percentage of clovers at the resident-range site and crimson clover at the seeded site decreased under grazing while rose and subclover were increased by grazing.

4076. Jones, Milton B. 1961. **Growth responses of annual range forage to seasonal application of urea.** Calif. Agric. 15(2):3-5.
Abstract: To test the efficiency of nitrogen fertilization on California annual rangelands, a 3-year study was made of forage yield and nitrogen uptake in relation to the dates of application of urea fertilizer. Forage produced in February was increased most by urea applied in September and least by urea applied in January. The May production of forage each year was increased by the application of urea fertilizer. For producing winter feed, September application of urea was more effective than November application, but for production of spring feed the date of application made no consistent difference, except that March application was too late to produce maximum yields. Application of phosphorus with the urea did not increase either February or May yield more than urea alone, indicating there was no phosphorus deficiency at the site of the experiment.

4077. Jones, Milton B., W. E. Martin, L. J. Berry, and V. Osterli. 1961. **Ground cover and plants present on grazed annual range as affected by nitrogen fertilization.** J. Range Manage. 14(3):146-148.
Abstract: Botanical composition was measured on nitrogen fertilized and unfertilized range at 11 locations in the California annual type range. Nitrogen fertilization increased the percentage of ground covered by plants. Annual grasses and filaree were the plants contributing to the increased ground cover on the fertilized pastures. In general, undesirable grass species did not dominate and crowd out more desirable grass species where nitrogen fertilizer was applied. The percentage of ground covered by legumes was reduced where nitrogen was applied the same season of sampling, but where nitrogen had been applied previous years and not in the season of sampling the percentage ground cover of legumes had either not changed or had increased slightly on the fertilized areas.

4078. Jones, Milton B. 1962. **Sulfur critical for maximum production of subterranean clover forage.** Calif. Agric. 16(11): 4-5.
Abstract: The relationship between sulfate sulfur in subclover plant tissues and sulfur deficiency was studied in the greenhouse and in the field. The critical concentration of sulfate sulfur in the tissue of subclover is about 170 ppm. Critical concentration is defined as that nutrient concentration which is just deficient for maximum growth. Sulfate sulfur concentration in whole subclover plants can be used to identify sulfur deficient plants, but it cannot be used to indicate the degree of deficiency. The availability of other elements for plant growth may affect the level of sulfate sulfur in the plant. For example, if phosphorus were more limiting than sulfur to plant growth, but sulfur was also low, the sulfate concentration in the subclover would likely be above the critical value until the phosphorus deficiency was corrected. Thus, the whole nutritional status of the plant must be considered.

4079. Jones, Milton B. 1962. **Total sulfur and sulfate sulfur content in subterranean clover as related to sulfur responses.** Soil Sci. Soc. Am. Proc. 26(5):482-484.
Abstract: Subclover was grown on sulfur deficient soil in the

greenhouse and in the field with various rates of S applied. Plants were harvested in the greenhouse when the first, third, and fifth flower per stem appeared, and the plant material was separated into leaflets, petioles, and stems. The total S and SO_4-S concentration in the plant did not change significantly over three stages of growth. More SO_4-S accumulated in the stems than in the petioles or leaflets at high rates of applied S, but at low levels of S there was little difference between the SO_4-S concentration of three plant parts. There was more organic -S in the leaflets than in other plant parts at all levels of applied S. The SO_4-S concentration was determined in whole subclover tops grown in the greenhouse on 13 soils fertilized with sulfur and phosphorus. The SO_4-S concentration in whole subclover plants showed the same relation to yield in the field as in the greenhouse. The SO_4-S concentration in subclover identified plants deficient in S, but did not indicate the degree of S deficiency.

4080. Jones, Milton B. 1963. **Effect of sulfur applied and date of harvest on yield, sulfate sulfur concentration, and total sulfur uptake of five annual grassland species.** Agron. J. 55:251-254.
Abstract: Five annual grassland species were grown competitively in the same pots at different levels of available S, and were harvested at 3 stages of maturity. There were differences in yield responses, SO_4-S concentrations, and total S uptake among the five species at different dates. Yield response of subclover, soft chess, and ripgut to S fertilization increased as the season advanced, but this increase was most outstanding in subclover. The concentrations of total S and SO_4-S decreased as the season advanced. Theses decreases were very small where no S was applied and were large at the higher rates of S. The SO_4-S concentration in each of the species where no S was applied was indicative of S deficiency. However, the SO_4-S concentration in subclover at flowering appeared to be the best single indicator of S status when all levels of available S were considered. Where no S was applied there was little or no uptake of S after the first harvest date, but where S was applied it continued to be absorbed up to the third harvest by subclover, soft chess, and ripgut. The increase over the check was much greater for subclover than for any of the other species.

4081. Jones, Milton B. 1963. **Nitrogen fertilization of north coastal grasslands: yield, percent protein, total uptake.** Calif. Agric. 17(12):12-14.
Abstract: The primary benefit of nitrogen fertilization to grassland areas of north coastal California was the increase in production of forage during the winter season when grass was short and legumes grew very slowly. According to these tests, not more than 80 pounds per acre should be applied since near maximum forage yields were produced at this rate and little increase in winter production resulted from additional amounts. However, carryover into the second year was measurable only with applications of the 160-pound maximum used in these tests on two soil types. Protein percentages in the nonleguminous plants increased with increasing N application rates during the vegetative stage, but at maturity, the nitrogen percentages in these plants were less where 40 pounds of N per acre had been applied than the non-treated check plots. The 160-pound rate increased the protein percentage in mature plants. Total nitrogen uptake of all forage species combined increased during the winter with increasing rates of N applied. However, uptake on the unfertilized plots during the warm spring months, when the clovers grew rapidly, was about the same as that on plots fertilized with 40 pounds of nitrogen per acre.

4082. Jones, Milton B. 1963. **Yield, percent nitrogen, and total nitrogen uptake of various California annual grassland species fertilized with increasing rates of nitrogen.** Agron. J. 55:254-257.
Abstract: Increasing rates of nitrogen fertilizer (as urea) up to 160 lbs/acre were applied to annual grassland on 2 soil types at Hopland. Yields, nitrogen concentrations, and nitrogen uptake were determined for individual species at 4 dates during the growing season. Near-maximum yields resulted where 80 pounds N per acre was applied, but carryover into the second year was measurable only where 160 pounds was used. In nonleguminous plants, percent N increased with N rates during the vegetative stage, but at maturity it was less where 40 pounds N was applied than in the control. N uptake increased with N rate during winter, but uptake on unfertilized plots during the spring approximated that on plots receiving 40 pounds of N.

4083. Jones, Milton B. 1964. **Effect of applied sulfur on yield and sulfur uptake of various California dryland pasture species.** Agronomy J. 56(2):235-237.
Abstract: A pasture of subclover, rose clover, and harding and annual grasses produced near maximum response the first year where 40 lbs of S per acre was applied as gypsum; however, the proportion of clover to grass continued to increase as the S rate increased to 80 lbs/acre. The carry-over effect into the second year from 80 lbs of S was roughly equivalent to 20 lbs of S the first year after application. During the cool winter season 20 lbs of S per acre produced maximum yields. The higher levels of S were not utilized for increased production until the warmer spring months. Subclover and hardinggrass had the greatest increase in total S uptake as the rate of S applied increased. The uptake in subclover resulted primarily from a large increase in total yield with a relatively small increase in percent S compared with hardinggrass, which increased relatively little in yield with increasing rates of S.

4084. Jones, Milton B. 1964. **Effects of sulfur on five annual grassland species.** Calif. Agric. 18(2):4-5.
Abstract: Differences in yield, sulfate-sulfur (SO_4-S) concentration, and total sulfur (S) uptake were found among five competing annual grassland species growing at different levels of available S at Hopland. Yield responses of subclover, soft chess, and ripgut to S fertilization increased as the season advanced, but the concentration of total S and SO_4-S in the plants decreased. Sulfur deficiency was indicated by the SO_4-S concentration in each of the species where no S had been applied. The SO_4-S concentration in subclover at flowering gave the best single indication of S status when all levels of available S were considered. Where no S was applied, there was little or no uptake of S after the first harvest date, but where S was applied, it continued to be absorbed by subclover, soft chess and ripgut up to the third harvest. The increase over the check was much greater for subclover than for any of the other species.

4085. Jones, Milton B., and W. E. Martin. 1964. **Sulfate-sulfur concentration as an indicator of sulfur status in various California dryland pasture species.** Soil Sci. Soc. Am. Proc. 28(4):539-541.
Abstract: Sulfate-sulfur values in subclover and soft chess under high N fertilization were approximately equal over a wide range of S fertilizer levels. With no fertilizer N, the SO_4-S values of annual grasses, including soft chess, were higher than those of rose or subclover. Hardinggrass was particularly high in SO_4-S. Where no N was applied the SO_4-S concentration in subclover decreased as the plants advanced from early vegetative to flowering stage. When plants began to wilt at the end of the season, the SO_4-S values increased over SO_4-S levels at flowering. Subclover and rose clover, sampled during the flowering period but before wilting, appeared to be the best plants for determining the S status of dryland pastures in California.

4086. Jones, Milton B. 1966. **Fertilizing annual grasslands in California.** Fert. Solutions 10(2):10-12,14.
Abstract: Proper fertilization is one of the most important practices needed in realizing the great potential from the annual grasslands of California. Application of nitrogen to the annual grassland pastures of California is very effective in increasing production. Sixty to 80

pounds of nitrogen per acre in the ammoniacal form should be applied in the fall before the first rains. Best results have been obtained in the 15- to 25-inch rainfall zones and adequate amounts of phosphorus and sulfur should be present. Phosphorus and sulfur are very effective in increasing annual grassland pasture production and quality in more humid areas when applied to subclover stands deficient in these elements.

4087. Jones, Milton B. 1966. **Forage and nitrogen production of nitrogen-fertilized California annual grasslands compared with a subclover-grass association (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 76.
Abstract: Production of forage and N by a subclover-grass mixture on plots of California annual-type pasture were compared with plots where no subclover was growing, but which were fertilized with various rates of N. In a year when rains commenced late in November and ended in March, stands of subclover-grass produced forage yields equivalent to those from California resident grasslands fertilized with 40 to 80 lb N/acre. In a year when rains commenced in early October and ended in May, the subclover-grass stands produced more forage than did resident grasslands fertilized with 160 lb N/acre. When total N taken up by the plants was the measure of comparison, subclover was equivalent to 80 to 100 lb N/acre in the dry year. In a wet year subclover-grass produced about double the N taken up by the plants where 160 lb N/acre was applied. The distribution of forage production and uptake of N was much more uniform in the plots seeded to subclover than in the N-fertilized plots. The applied N was taken up rapidly, giving high concentrations of N within the plants; when this was removed by grazing or by mowing, little N remained for future growth.


A. H. Murphy

Agronomist Milton Jones examines annual grass response to sulfur, Vassar Corner, February 1968

4088. Jones, Milton B., and J. E. Ruckman. 1966. **Elemental S advocated for grasslands.** Crops and Soils 18(5):22.
Abstract: Over a 4-year period, sulfate sulfur or elemental sulfur was applied to grass-legume pastures of northern California to investigate the effects of these treatments on forage production. Control check plots not receiving sulfur fertilization yielded an average of 1,800 lbs/acre. Application of gypsum or elemental sulfur nearly doubled forage production the first season. The amount of clover increased from 12% in the checks to about 60% in both sulfur treatments. The uptake of sulfur rose from 1.2 lbs/acre where no sulfur was applied to over 4 lbs/acre where either gypsum or elemental sulfur was applied. Treatment effect diminished after the first year. Based on this and other studies, we believe an application of 40 lbs S per acre either as gypsum or as elemental sulfur is adequate for maximum production of forage from annual grasslands during the first year after application. During the second, third, and fourth years, elemental sulfur was superior to gypsum. It is our opinion that long-lasting properties of elemental sulfur make it more desirable than gypsum on grasslands. The amounts of elemental sulfur used should be moderate because it increases soil acidity.

4089. Jones, Milton B., and J. E. Ruckman. 1966. **Gypsum and elemental sulfur as fertilizers on annual grassland.** Agron. J. 58(4):409-412.
Abstract: Gypsum and elemental S, each fine enough to pass through a 100-mesh screen, were applied at equivalent rates in each of 4 years to soils deficient in S. Forage yields, percent clover, total S uptake, and concentration of S in the plants were recorded over a 5-year period. The two sources of S were equally effective in increasing yield, S uptake and concentration in the forage, and percentage of clover in the stand the first season after application. However, more S from gypsum than from elemental S was taken up during the winter of the first year, while the reverse was true for the following spring. In the second season after treatment, forage production from elemental S approximated that of the first year; however, yields from gypsum were significantly less than in the first year. In subsequent years forage production declined until there was no significant effect from gypsum in the fourth season nor from elemental S in the fifth season. A significant increase in S uptake and percent S in the forage from gypsum was measured the second year; however, with elemental S a significant increase in S uptake persisted through the third year. Percentage clover declined rapidly with each additional year following application with the decline more rapid where gypsum was applied. Efficiency of the S applied varied from 13 to 34%.

4090. Jones, Milton B. 1967. **Forage and nitrogen production by subclover-grass and nitrogen-fertilized California grassland.** Agronomy J. 59:209-214.
Abstract: A 3-year study was made with resident annual grasses and broadleaf herbs in 3 management systems and 8 fertility treatments. In a moisture-deficient year (rains commencing late in November and ending in March), stands of subclover-grass produced forage yields equivalent to those from California annual-type grasslands fertilized with 45-90 kg N/ha. Uptake of N by subclover was equivalent to 90 to 179 kg N/ha in this dry year. In a moisture-adequate year (rains commencing in early October and ending in May), subclover-grass stands produced more forage than did resident grasslands fertilized with 179 kg N/ha. Nitrogen fertilization made its most valuable contribution to forage production during the winter period. Second and third year stands of subclover also increased production early in the season but made the greatest gains in April and May.

4091. Jones, Milton B. 1967. **Forage and protein production by subclover-grass and nitrogen-fertilized California grasslands.** Calif. Agric. 21(10):4-7.
Abstract: Range grass areas including stands of subclover produced forage yields equal to those from nitrogen-fertilized annual grasslands in a moisture-deficient year in northern California, and more forage was produced in a moisture-adequate year, according to this study. Stands of subclover and grass produced forage yields equal to those from California annual-type grasslands fertilized with 45 to 90 kg of nitrogen (N) per hectare (45 kg N/ha = 40 lb/acre), in a moisture-deficient year (when rains began in late November and ended in March) and a moisture-adequate year (with rains commencing in early October and ending in May), subclover-grass stands produced more forage than did resident grasslands fertilized with 179 kg N per ha. Nitrogen fertilization was found to contribute most to forage production during the winter period. Second and third year stands of subclover also showed production increases early in the season, but made the greatest gains in April and May.

Bruce Bearden

Agronomist Milton Jones and Superintendent Al Murphy at site of forage improvement trial, Winter 1965

4092. Jones, Milton B., and S. Sherwood Winans. 1967. **Subterranean clover versus nitrogen fertilized annual grasslands: botanical composition and protein content.** J. Range Manage. 20(1):8-12.
Abstract: The effect of increasing levels of N applied to nonirrigated California grasslands was compared to swards of subterranean clover-grass under three types of management: grazed, mowed, and ungrazed-mowed. Establishment of a subterranean clover stand with resident annual grassland species, or in a stand of hardinggrass, reduced the percentage of all species present other than subterranean clover in each of the three types of management except on the ungrazed-unmowed treatment where California burclover percentage remained high. Subterranean clover was most competitive on grazed or mowed plots. But clover percentages were reduced by grazing. Application of increasing rates of N increased the percentage of annual grasses and decreased that of native legumes in the three management treatments. The percentage of hardinggrass did not consistently increase except when the highest rate of N was applied. Protein levels in forage from subterranean clover plots were as high or higher during the winter period as where 80 lb N/acre had been applied. As the season advanced, protein levels remained high longer on subterranean clover plots, and did not drop to such low levels as where N had been applied. Fall-applied N increased the protein percentage in the forage during the winter and early spring. At plant maturity, the percentage of protein in the forage was lower where N had been applied than where it had not. As indicated in previous studies, this resulted from a decrease in the percentage of legumes and also from a decrease in the level of protein in the grass species. In areas with less rainfall, the addition of N to annual grasslands may increase the protein level, because all of the applied N is not utilized in plant growth. But in the higher rainfall areas of the state, protein levels are likely to be decreased at plant maturity by the application of N the preceding autumn.

4093. Jones, Milton B., W. E. Martin, and William A. Williams. 1968. **Behavior of sulfate sulfur and elemental sulfur in three California soils in lysimeters.** Soil Sci. Soc. Am. Proc. 32(4):535-540.
Abstract: Three soils from diverse climatic regions of California were placed in free-draining lysimeters, and sulfur was applied as gypsum, fine elemental S (particles <0.1 mm), or pelleted elemental S (0.5 to 0.9 mm in diameter), at the rate of 56 kg S/ha (1,135 mg S per lysimeter). All S fertilizers were tagged with radioactive S. Sulfur uptake by soft chess (*Bromus mollis*), and S in leachate, and in runoff was measured. Recovery of S by the plant was greater in the fine elemental S treatment than in the gypsum treatment on the two soils where the loss of gypsum S by leaching was greater. Concentrations of S in the leachate were generally highest in the gypsum treatment in the first year after treatment. Timewise, concentrations were generally highest when the first percolate of the rainy season came through the soil. From 80 to 90% of the applied gypsum S, about 50% of the fine elemental S, and 10 to 15% of the pelleted elemental S was accounted for in a 4-year period. Most of the gypsum S was accounted for in the first year. In contrast, most elemental S was recovered in subsequent years. Willits loam held gypsum S against leaching much better than did soils of the "Hebron" or Sehorn series, and the uptake of gypsum S was higher from Willits soil than from the other two soils.

4094. Jones, Milton B., and J. E. Ruckman. 1968. **Effect of particle size on long-term availability of sulfur on annual grassland (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 105.
Abstract: Elemental S and gypsum were applied to separate plots in a subclover-grass pasture at 45 or 448 kg/ha. Diameter of the S particles was < 0.15 mm, 0.25-0.29 mm, 0.30-0.59 mm, or 0.84-2.00 mm. Forage yields, changes in botanical composition, and S uptake were determined annually for 7 years after application. At the 448 kg level, uptake of S from the smallest-sized particles was highest during the first 2 years. Thereafter it decreased annually. Uptake of S from gypsum followed a similar pattern, but the decrease was more rapid. With the 0.25-0.29 mm particles, uptake was less than from the smallest particles the first year; but the level remained relatively constant for 3 years, with only small decreases in subsequent years. Uptake of S from the 0.30-0.59 mm particles was less than half that from the finest S the first year after application, but there was no decrease in uptake with time. Also, the uptake was about twice that from the largest-sized particles throughout the period of the experiment. Where 45 kg S/ha were applied, comparative S uptake from the various sized particles was similar to that with the 448 kg application. Application of 448 kg S decreased soil pH markedly in the surface inch.

A. H. Murphy

HFS staff supervisor Ken Whittaker applies fertilizer to Upper Horse pasture, October 1969

4095. Jones, Milton B., and J. E. Ruckman. 1969. **Effect of particle size on the long term availability of sulfur on annual-type grasslands.** Agron. J. 61:936-939.
Abstract: Elemental sulfur and gypsum were applied to separate plots in a subclover (*Trifolium subterraneum*)-grass pasture at 45 or 448 kg/ha. Diameter of the S particles was <0.15 mm, 0.25-0.29 mm, or 0.84-2.00 mm. Forage yields, changes in botanical composition, and S uptake were determined annually for 7 years after application. At the 448-kg level, uptake of S from the smallest sized particles was highest during the first 2 years. Thereafter it decreased annually. Uptake of S from gypsum followed a similar pattern, but

the decrease was more rapid. With the 0.25-0.29 mm particles, uptake was less from the smallest particles the first year but the level remained relatively constant for 3 years, with only small decreases in subsequent years. Uptake of S from the 0.30-.59 mm was less than half from the finest S the first year after applications, but there was no decrease in uptake with time. Also the uptake was about twice that from the largest sized particles throughout the period of the experiment. Where 45 kg S/ha was applied, relative amounts of S uptake from the various sized particles were similar to that with the 448 kg application in the first year after application except that the amounts were much less. In subsequent years the increase in S uptake caused by application of the finest S decreased more rapidly than where the heaviest rate was applied. Also, the cumulative S uptake from coarse S fractions did not exceed uptake from the finest S, as it did where heavier S was applied. Where 45 kg S/ha was applied, increased forage production was closely related to S availability, particle size, and S uptake. Increases in forage production with the application of 448 kg S did not follow the same pattern as S uptake with regard to particle size. Yield increases were least where <0.15 mm particles were used. This probably was caused by side effects, since soil pH was reduced by the heavy application of the finest S.

4096. Jones, Milton B., P. W. Lawler, and J. E. Ruckman. 1970. **Differences in annual clover responses to phosphorus and sulfur.** Agron. J. 62:439-442.
Abstract: Many new varieties of winter annual legumes are now available for pastures in Mediterranean type climates. Since little work has been reported comparing the relative responses of these legumes to fertilization, 10 varieties of subclover, 6 of rose clover, 3 annual Medicagos, and 2 other annual clovers were grown in the greenhouse on a soil known to be deficient in P and S. Highest yielding clover varieties tended to have lowest percentages of P and S. Differences in P and S uptake by the clover varieties were significant; however, uptake responses to fertilization tended to be relatively smaller than yield responses differences, indicating that some varieties utilized absorbed nutrients more efficiently than others. Response to fertilization apparently must be considered on a varietal basis rather than generalizing about species.

4097. Jones, Milton B., W. E. Martin, and J. E. Ruckman. 1970. **Effectiveness of various sulfur sources applied to annual-type grasslands of California.** Proc. XI Int. Grassland Congr., pp. 373-376.
Abstract: An elemental sulfur-bentonite mixture was compared with fine elemental sulfur (particles <0.15 mm), and fine gypsum, each applied at an equivalent rate of 45 kg S/ha to annual grassland pasture at 2 locations. In the season of application, elemental S and gypsum provided equal amounts of S, but S-bentonite was less effective. In the second season, residual elemental S and S-bentonite supplied equal amounts of S, but gypsum supplied least. In the third season, residual S-bentonite supplied most followed by elemental S then gypsum.

4098. Jones, Milton B., W. E. Martin, and J. E. Ruckman. 1970. **Sulfur fertilizers evaluated on California grasslands.** Sulphur Instit. Journal 6(2):2-4.
Abstract: The effect of S-bentonite prills was compared to that of finely divided elemental S and gypsum in terms of sulphur uptake and forage yields over 3 years after application to northern California annual pastures. The sulphur in sulphur-bentonite prills was less available to plants than finely divided elemental sulphur or gypsum in the first year after application. This was reflected in both S-uptake and forage yields. The fact that S-bentonite produced greater third season residual effects on uptake and yields also reflects the slower availability of the sulphur in this material. The release of sulphur by S-bentonite was more uniform over the 3-year period than it was from either finely divided S or gypsum. This work indicates that gypsum supplied sufficient sulphur for plant growth for only one year, finely divided elemental S supplied sufficient sulphur for two years, and sulphur-bentonite prills released sulphur fairly uniformly over a period of three years. This could be of considerable economic importance and can be set against the additional cost of the sulphur-bentonite prills.

4099. Jones, Milton B., J. H. Oh, and J. E. Ruckman. 1970. **Effect of phosphorus and sulphur fertilization on the nutritive value of subterranean clover (*Trifolium subterraneum*).** Proc. New Zealand Grassland Assoc. 32:69-75.
Abstract: Phosphorus or sulfur applied alone to a soil deficient in P and S did not increase subterranean clover yields; but when the two elements were applied together, a five-fold increase was obtained. The nutritive value of the clover was evaluated by measuring sheep rumen microbial activity using anaerobic manometric technique. Subclover fertilized with P alone increased the microbial activity about 6%. In contrast, the clover fertilized with S alone decreased activity about 5%. When P and S were applied together microbial activity was increased 20% to 30% depending on the rates applied. There was a positive correlation between the level of reducing sugars in the clover and the degree of rumen microbial activity.

4100. Jones, Milton B. 1971. **Use of plant analysis in annual grassland species.** Pp. 59-64 *in:* Proc. Statewide Conf. on Soil Tissue Testing.
Abstract: Critical levels of P, K, and S have been determined for the principal legume species of California and for ryegrass. Studies with mixed annual grass-clover stands have shown that S status of the plant community is best evaluated from analysis of the legume rather than of the grass component. Nitrogen-deficient grasses usually have S concentrations well above the critical levels. Only when sufficient N has been applied to correct any N deficiency will S deficiency of grasses occur. Any factor that limits growth, such as light, moisture, temperature, defoliation by grazing or clipping, or nutritional disorder may cause other nutrients to accumulate in a plant.

Agronomist Milton Jones (right), research cooperator Joe Burton (left), and a visitor inspect subclover inoculation plot, Spring 1967

4101. Jones, Milton B., Patrick W. Lawler, and Alfred H. Murphy. 1971. **Establishment of subclover in relation to nodulation, time of seeding, and climatic variations.** J. Range Manage. 24(2):147-150.
Abstract: Pellet-inoculated subclover (*Trifolium subterraneum*) seed planted at various autumn dates on a site where effective nodulation was known to be a problem, produced healthy plants when mean ambient air temperature in the 6 weeks following germination was between 49° and 62°F. When mean temperature for the 6-week

period was about 45°F, very poor clover stands developed. Seed planted September 10, about one month before a rain, produced a good stand of vigorous clover. This indicated that sufficient viable inoculum had survived in dry soil on the pelleted seed until rain came. It is recommended that where subclover is adapted, plantings be made in October rather than waiting until after the soil is wet. More vigorous clover grew from seed which was in the ground at the time of the first rain than from seed drilled soon after the rain.

4102. Jones, Milton B., William A. Williams, and W. E. Martin. 1971. **Effect of waterlogging and organic matter on the loss of applied sulfur.** Soil Sci. Soc. Am. Proc. 35(4):542-546.
Abstract: A study was conducted to determine the effect of waterlogging and of organic matter on leaching of sulfur during wintertime precipitation. Gypsum and elemental S (56 kg/ha) were applied to lysimeters before the first fall rains. Waterlogging and barley straw (*Hordeum vulgare*) (11,200 kg/ha) were additional variables imposed in all possible combinations. Nitrogen was applied uniformly to all tanks, and cereal and grass were grown during two seasons. In the first year after applications of gypsum, 45 and 41 kg/ha S were recovered in the leachate from freely drained soil with and without straw, respectively. The free-draining tanks treated with elemental S gave values of 10 and 7 kg/ha S recovered in the leachate for the straw and no straw treatments. Waterlogging decreased leaching loss of sulfur by an average of 40%. Oats (*Avena sativa*) planted when waterlogging was discontinued took up more S in the absence of straw and also more S was leached than on freely drained treatment. However, no significant increase in uptake occurred in the succeeding grass crop as a result of the sulfur conserved by the waterlogging. It is concluded that where waterlogging occurs during the winter months in annual-type range soils, SO_4-S leached from either applied or natural sources of sulfur is likely to be decreased, but also that sulfur conservation by this means is unlikely to aid the production of grasslands in California.

4103. Jones, Milton B., J. H. Oh, and J. E. Ruckman. 1972. **Effect of S & P on nutritive value of clover.** Sulphur Instit. J. 8:2-5.
Abstract: Phosphorus or sulfur applied alone to a soil deficient in P and S did not increase subterranean clover yields; but when the two elements were applied together, a five-fold increase was obtained. The nutritive value of the clover was evaluated by measuring sheep rumen microbial activity using anaerobic manometric technique. Subclover fertilized with P alone increased the microbial activity about 6%. In contrast, the clover fertilized with S alone decreased activity about 5%. When P and S were applied together microbial activity was increased 20% to 30% depending on the rates applied. There was a positive correlation between the level of reducing sugars in the clover and the degree of rumen microbial activity. This study was designed to determine the critical levels of P and S for rumen microbial activity. It is probable that the highest level of P and S used in this study was suboptimal for plant growth, but was adequate for rumen microbial activity.

4104. Jones, Milton B., J. E. Ruckman, and Patrick W. Lawler. 1972. **Critical levels of sulfur in bur clover.** Agron. J. 64:55-57.
Abstract: Sulfur deficiencies are widespread in areas of California annual grassland where bur clover (*Medicago hispida*) is an important legume. The growth of this species is greatly increased by applications of S where S is deficient. The purpose of this study was to obtain information useful in assessing the sulfur status of annual grasslands in which bur clover occurred. The clover was grown in nutrient solution with varying levels of available S. Total S and SO_4-S concentrations in immature and mature leaves and in middle and lower stems were studied in relation to dry matter production. The concentration of total S where yields were 95% of maximum ("critical concentrations") was 0.225% for both immature and mature leaf blades and was 0.080% for middle and lower stems. The "critical concentrations" for SO_4-S were 160, 140, 100, and 160 ppm for immature and mature leaves and middle and lower stems respectively. Organic S (total S minus SO_4-S) reached a maximum at about 0.250% in leaves and about 0.100% in the stems. Where S was applied in luxury amounts, unmetabolized sulfur accumulated as SO_4-S. Highest concentrations were found in the lower stems, lesser amounts in the upper stems, and least SO_4-S was found in the leaves.


Milton B. Jones

Bur clover plants in greenhouse, March 1968

4105. Jones, Milton B., J. E. Ruckman, and Patrick W. Lawler. 1972. **Critical levels of P in subclover (*Trifolium subterraneum*).** Agron. J. 64:695-698.
Abstract: Phosphorus deficiencies are widespread in California annual grasslands and in other areas of the world where subclover (*Trifolium subterraneum*) is an important legume. Therefore, the effects of clipping frequency and stage of growth on critical levels of P in subclover were studied. Critical P level was defined as percent P in the clover part when lack of P limited clover yields to 95% of those obtained with adequate P. In pot experiments subclover was grown in P-deficient soils fertilized with increasing amounts of P until no additional increase in yield was obtained. When leaves were sampled from plants 48 to 151 days of age, the critical level decreased from 0.61% to 0.11% P, but changes after 120 days were not statistically significant. At day 120, leaves from plants previously defoliated 0, 1, 2, or 3 times had critical values of 0.11%, 0.18%, 0.23%, and 0.28% P, respectively. The last three determinations were for leaves of the same physiological age harvested 13 days after the previous clipping. At 120 days, critical P values in stem tissue also increased with increasing frequency of defoliation.

4106. Jones, Milton B., and J. E. Ruckman. 1973. **Long-term effects of phosphorus, sulfur, and molybdenum on a subterranean clover pasture.** Soil Sci. 115(5):343-348.
Abstract: Phosphorus, S, and Mo were applied alone and in all combinations on a grassland pasture deficient in P and Mo, and sown to subterranean clover (*Trifolium subterraneum*). Effects on yield and chemical composition of the plants were observed for a 6-year period after treatment. During the first 2 years of the study, highest forage yields occurred where a combination of P and Mo were applied, and inclusion of S did not have an appreciable effect. The P-S treatment produced less forage than did P alone. Responses to S and Mo without P were relatively small. In the third, fourth, and fifth years there was a definite response to S where applied with P or P-Mo. The yield response to the three elements diminished with time. The percentage of P in subclover increased with application of P and decreased with time where S and Mo were applied with the P. Application of S or Mo did not effect percent P in the clover where no P was applied. The SO_4-S levels in subclover were increased by applying S. Both P and Mo treatments decreased in S concentrations,

which was probably a dilution effect. The SO_4-S levels in subclover from plots fertilized with S decreased sharply in the first 3 years of the study. Molybdenum concentrations were increased in subclover by applying Mo, and reduced by applying S. There was an inverse relationship between concentrations of Mo and SO_4-S, either comparing treatments in a given year or comparing years.

4107. Jones, Milton B. 1974. **The need for sulfur is widespread.** Grow, Austr. Fertil. Ltd., pp.4-8.
Abstract: There are several ways of recognizing a sulfur deficiency. The surest way is to apply several strips of sulfur over the field to be tested. A second method of detecting a sulfur need is by observing the growing crop. A third means of assaying the sulfur status of a crop is by chemical analysis of the plant material. Another method of diagnosing sulfur status that has been tried is soil testing.

4108. Jones, Milton B. 1974. **Fertilization of annual grasslands of California and Oregon.** Pp. 255-275 *in:* D. Mays (ed.), Forage Fertilization. Am. Soc. Agron, Madison, WI.
Abstract: The annual grasslands of the California and Oregon extend from coastal southern California to central Oregon. In this region of Mediterranean climate, rainfall occurs during the cool season of the year. Rainfall can be quite variable with some growing seasons being less than 6 months. Annual grasslands produce feed in a "feast or famine" cycle each year. During the winter season, after the arrival of germinating rains, the green feed is high in protein, but low in quantity. By early spring, supply is usually sufficient, and by late spring reserve supplies are built up. When the forage dries in the summer, livestock must survive on dry feed until the next fall's rains. This seasonal and annual variation in pasture growing conditions can be ameliorated with fertilization and seeding with improved plant species. The soils are nearly always deficient in N. The addition of N fertilizers, or seeding with legumes, produces more high protein forage early in the growing season when supply is low. Phosphorus and S deficiencies are also widespread. Supplementation with these nutrients also improves forage quality and quantity, particularly with legumes. In some areas, deficiencies of Mo, K, B, and lime have been found, but they are not widespread. Annual range has been made 3 to 12 times more productive when improved plant species were planted and properly fertilized.

4109. Jones, Milton B., and J. E. Ruckman. 1974. **Available calcium and response of subclover growing on serpentine-type soils.** Pp. 3(a), 63-66 *in:* Proc. Austr. Soil Sci. Conf., Melbourne, Victoria, Australia.
Abstract: In establishing a good stand of clover and grass on serpentine-type soils of the Lake Berryessa watershed in northern California, heavy to light applications of Ca will be required on many sites, and none on others. A valuable aid in distinguishing between such sites is soil testing and tissue analysis. Presently showing some promise is color infrared aerial photography, now being investigated as a survey tool for soil Ca levels. Tests indicated that P and S should be applied to all sites, and that most would benefit from Mo applications. However, stands would probably survive without it, at least until the effects of Mo applications on Mo levels in water runoff could be studied. Applications of K should probably be made in years subsequent to clearing as the need becomes evident.

4110. Jones, Milton B., J. E. Street, and William A. Williams. 1974. **Leaching and uptake of nitrogen applied to annual grass and clover-grass mixtures in lysimeters.** Agron. J. 66(2):256-258.
Abstract: The annual grassland soils of California are nearly always N deficient. If early winter feed is desired and total production is to be increased, N must be added, either by a legume or through N fertilization. Comparison of these two N sources in terms of forage and protein production and groundwater pollution is important for efficient management of land, water, and N resources. This study was initiated to measure the effect of N fertilization on forage yields, N-uptake by the plants, and N leached from the soil where grass grew alone or from clover-grass mixtures. Grass (soft chess, *Bromus mollis*) growing alone, grass plus subclover (*Trifolium subterraneum*), and grass plus rose clover (*T. hirtum*) were grown in lysimeters on Josephine soil with and without N applied in the autumn of each of 4 years. Nitrogen fertilization increased winter forage yields and N-uptake in all species mixtures. However, in the spring harvest, clover-grass mixtures yielded as much forage and N-uptake without N as with N applied. Apparent recovery of the applied N in the forage was 25% for the grass, -2% for the subclover-grass, and 0% for the rose clover-grass. The amount of apparent fertilizer N found in drainage water was 37% from grass, 58% from subclover-grass, and 50% under rose clover-grass. Without N fertilization, the N leached was about the same from clover-grass as from grass alone. Of total N leached, 94% was in the fall, 6% in winter, and less than 1% in spring, whereas the total drainage water was divided 43% in the fall, 54% in winter, and 3% in spring. With N fertilization, NO_3-N in the water in the fall was 45 ppm from clover-grass and 38 ppm from grass. Without applied N, the NO_3-N values were 25 ppm in the fall and were 1/10 as great in winter and about 1/100 in spring. There was no rain in the summer.

4111. Jones, Milton B. 1975. **Sulfur in agricultural land.** Pp. 141-158 *in:* H. Parker (ed.), Sulfur in the Environment. Missouri Bot. Garden, St. Louis, MO.
Abstract: Sulfur is essential for the production of our food supply. Growing crops may obtain sulfur along with other elements from the soil, but the soil supply will be depleted by the crops and by leaching rains if it is not replaced on a regular basis. This replacement is necessary to obtain satisfactory crop production. Sulfur may be added to the soil by fertilizers, in the rain, or the plants may absorb it as sulfur dioxide from the air. The results will be the same regardless of source, provided concentrations are high enough to supply but not too high to become toxic. Crop diagnostic criteria for low and high critical values must be considered on an individual crop basis.

4112. Jones, Milton B. 1975. **Plant assays for the recognition of sulfur deficiency.** Pp. 175-181 *in:* K. D. McLachlan (ed.), Sulfur in Australasian Agriculture. Sydney Univ. Press, Sydney, Australia.
Abstract: The following criteria for assessing the S status of pasture plants were discussed: Total S, reducible S (SO_4-S), N:S ratios, biochemical tests and physiological assessments. To be useful to agriculture over a wide range of conditions a plant assay for the recognition of sulfur deficiency must be fast and inexpensive. Sampling procedures must be simple enough that farmers can take them, and then send to distant laboratories and get back meaningful results. Running reducible S on dried plant material had the advantage of not requiring the separation of plant parts (such as stems and leaves) that is required with total S; however, reducible S values usually have higher coefficients of variation than total S values. The procedure used might well depend upon how the laboratory is equipped. The N:S ratio can be used when some special instances where testing facilities are close to the source of fresh plant material.

4113. Jones, Milton B., Charles E. Vaughn, and Robert S. Harris. 1975. **Calcium nutrition of subclover growing on serpentine soils (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 139.
Abstract: Calcium was applied as $CaSO_4$ at 6 rates to 7 calcium-deficient serpentine soils in pots and seeded to Geraldton subclover for the purpose of determining the level of Ca required to obtain maximum yields. Basal applications of P, K, S, and Mo were applied to all treatments. Calcium and Mg concentrations were determined in "young" and "old" subclover leaves and stems. Critical Ca percentages (the concentration of Ca where yields were 90% of maximum) ranged from 0.40% to 0.66% Ca in young leaves, 0.75% to 1.38% in old leaves and 0.29% to 0.37% in new and old stems.

Critical Ca/Mg ratios ranged from 0.42% to 0.78% in new leaves, 0.42% to 0.70% in old leaves and 0.31% to 0.48% in young stems. It was concluded that for assaying the Ca status of subclover a specific plant part should be used rather than the whole tops. Also, that both Ca percentage and Ca/Mg ratios were useful in predicting a response to applied Ca. Where either percent Ca or the Ca/Mg ratios were below the critical level, a Ca response would be expected if there were no other limiting factors. If both values were above the critical range, a response to Ca would not be expected.

HFS research associate Bob Harris analyzes sample in gas chromatograph, October 1971

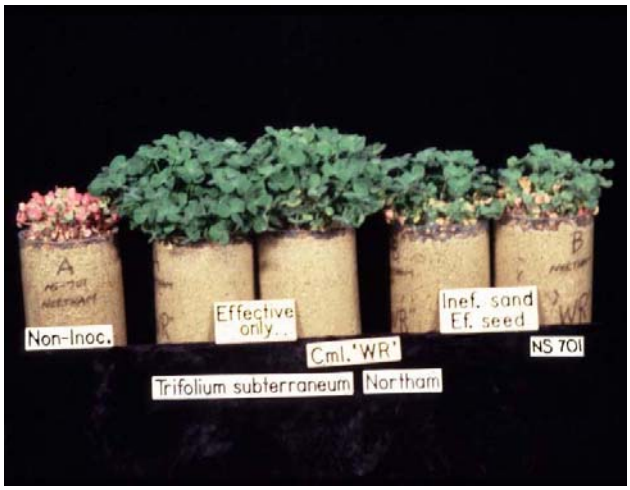
4114. Jones, Milton B. 1976. **Fertility studies reveal plant and soil needs.** Calif. Agric. 30(7):13-15.
Abstract: California's annual grasslands can be deficient in a number of elements. Studies of the effects of fertilization, including application of nitrogen, phosphorus, sulfur, and molybdenum, are reviewed. The forage value of introducing subclover to annual grasslands, and the importance of effective inoculation of subclover seed with *Rhizobium* bacteria at planting, are noted. The unique fertility requirements of serpentine soils are discussed.

4115. Jones, Milton B. 1976. **Plant tissue analysis - annual legumes.** Pp. 29-31 *in:* H. M. Reisenauer (ed.), Soil and Plant Tissue Testing in California. Bulletin 1879, Div. Agric. Sci., Univ. Calif.
Abstract: The critical concentrations of P, K, and S in some annual clovers are listed. Values vary with stage of growth, plant part, presampling defoliation frequency, and analytical methods. It is important that each of these conditions be standardized in order to obtain valid diagnostic data. This standardization of conditions for taking samples appears to be most critical with P. Available soil P as measured by the $NaHCO_3$ method gives a more satisfactory assessment of the P fertilizer needs of annual grassland pastures than does plant tissue analysis. Soils have extractable P values less than 5 ppm are considered very P-deficient. Values above 10 ppm indicate adequate P. However, some responses occur on the latter soils. The time since fertilizer was last applied is an important factor regardless of soil test.

4116. Jones, Milton B. 1977. **Using critical nutrient levels on California annual grasslands (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 159.
Abstract: Nitrogen, P, and S are the nutrients most commonly deficient on the annual grasslands on northern California. Nitrogen may be eliminated as a factor to be tested for by using legumes. In assaying P status, soil analysis has been more satisfactory than plant analysis. Plant P values fluctuate widely with plant age and pasture management. A good relationship exists between extractable soil P and yield, but the length of time since the last P application is also an important consideration. In diagnosing the S status, plant analysis has proven more satisfactory than soil analyses, which do not correlate well with plant growth. Some factors which influence the nutrient concentrations in plants and thus the critical values obtained in nutrient trials are as follows: plant species, stage of growth, and plant part; environmental factors such as moisture stress, grazing pressure (degrees of defoliation and competition among species), the level of nutrients other than the one under study, or growth depressing elements; and analytical procedures. Legumes have proven most satisfactory of the pasture species in assaying for P and S since they are not dependent on soil N for their growth.

4117. Jones, Milton B., C. C. Delwiche, and William A. Williams. 1977. **Uptake and losses of ^{15}N applied to annual grass and clover in lysimeters.** Agron. J. 69:1019-1023.
Abstract: The California annual grasslands comprise about one-third of the state, and they play a large role in the hydrology of most watersheds in central and northern California. Apparent recovery of applied N has been low, and a large percentage has been unaccounted for in N balance studies. The present experiment was done with ^{15}N to determine the fate of applied N, especially that leached and that volatilized (by difference). Ammonium sulfate labeled with ^{15}N ammonium chloride was applied to pure stands of soft chess (*Bromus mollis*) and subclover (*Trifolium subterraneum*) growing in lysimeters in a climate with mild, rainy winters and hot, dry summers. Uptake and leaching of N were measured on single and repeated applications for 3 years (mean annual rainfall 1,100 mm). After 3 years of annual fertilization in February (100 kg N/ha) 59% of N applied to grass was removed in forage, 24% remained in the soil and roots, 3% leached, and 14% was not detected (presumed gaseous loss); for clover 49% was removed in the forage, 33% remained in soil and roots, 9% leached, and 9% was not accounted for. October fertilization at the same rate produced in both species about the same total growth, markedly decreased plant uptake, increased soil-plus-root retention, increased leaching, and reduced unaccounted for N from fertilizer. An October application of 500 kg N/ha resulted in greater gaseous losses of N, and more was lost from clover than grass. Conclusions: There was modest leaching loss but essentially no gaseous loss from moderate rates of N applied to grass in October; there was almost negligible leaching loss but modest gaseous loss from moderate rates of N applied to grass in February; recovery of fertilizer by clover was poor; and a single large application (500 kg N/ha) resulted in a substantial leaching and gaseous losses under both grass and clover.

4118. Jones, Milton B., William A. Williams, and J. E. Ruckman. 1977. **Fertilization of *Trifolium subterraneum* growing on serpentine soils.** Soil Sci. Soc. Am. Proc. 41(1):87-89.
Abstract: Serpentine-derived Henneke soil from 23 sites was tested in greenhouse studies to determine nutrient deficiencies for subclover (*Trifolium subterraneum*), and to evaluate for soil Ca status. The soils (pH 6.3-6.9) were generally very deficient in P and S. When P and S were supplied, Ca increased subclover yields on 17 of the 23 soils, K on 10 soils, and Mo on 14 soils. Applications of P and S increased these two elements in clover tops from below critical levels to adequate. Yields were correlated with Ca and Mg in the plant and soil by the equation: $Y = a[1-b \exp(-cX)]$, where Y = relative yield, X = the variable under study, and a, b, and c are coefficients which determine the characteristics of the curve. The R^2 values which are a measure of goodness of fit, occurred in descending order as follows: Percentage of Ca in clover tops > exchangeable Ca expressed as a percentage of the cation exchange capacity > exchangeable soil Ca > ratio of Ca/Mg in the clover tops = ratio of exchangeable Ca expressed as a percentage of the sum of exchangeable cations. The R^2 values were significant at the 1% level.



Varieties of subterranean clover and with their bacterial innoculants, appropriate for improving forage on North Coast rangelands, were developed by Agronomist Milton Jones and his colleagues and students.

4119. Jones, Milton B., J. C. Burton, and Charles E. Vaughn. 1978. **Role of inoculation in establishing subclover on California grasslands.** Agron. J. 70:1081-1085.
Abstract: Subclover (*Trifolium subterraneum*) has been difficult to establish in California annual grasslands even with approved cultural, inoculation, and fertilization practices. Symptoms indicated a *Rhizobium* insufficiency. The objectives of this study were to develop dependable inoculum and methods of establishing annual clovers in northern California. Rhizobia were isolated from nodules of vigorous clover plants growing among plants showing extreme N-deficiency symptoms. These rhizobia were screened in growth chamber tests for effectiveness and competitiveness against native ineffective rhizobia. The best strains were further tested in the field with several stickers and seed coating materials, and were compared with commercial inoculants available at the time. In the field tests rhizobial strains differed in ability to compete with ineffective native rhizobia and in ability to survive the long summer drought. In composites, poor or moderately effective rhizobial strains reduced the effectiveness of the good strains. Subclover growth was increased in field experiments as the amount of inoculum was increased, indicating that high rhizobial numbers were important. Peat inoculum applied with 40% gum arabic solution as a sticker and a lime coating was much superior to peat inoculum applied as a water slurry. Vacuum-inoculation treatment gave no better results than uninoculated seed. The effectiveness of inoculation sticker materials fell generally in the following order: "PELGEL-PELINOC" > gum arabic-lime > methyl cellulose-lime > sugar lime.

4120. Jones, Milton B., and Burgess L. Kay. 1978. **Fertilizer responses on an Auburn soil of the University of California Sierra Foothill Range Field Station.** Agron. Prog. Rep. 88, Agric. Exp. Stn., Coop. Ext., Univ. Calif. Davis. 6 pp.
Abstract: A previous greenhouse experiment using subclover on Auburn soil from the Sierra Foothill Range Field Station indicated a clear response to phosphorus and sulfur, as well as a significant response to molybdenum. Our field tests conducted on the same soil site indicated the soil was marginally deficient in P and S for maximum subclover growth. However, the results were inconclusive because of the highly variable soil, weather, and poor clover stand in most years of the study.

4121. Jones, Milton B., William A. Williams, Charles E. Vaughn, and K. Mayalagu. 1978. **Site and soil characteristics influencing annual grassland yields (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 156.
Abstract: Plots were established on 22 California annual grassland sites with the objective of determining which of the site-soil characteristics were most important in determining forage yield of a grass-clover sward. Plot sites were distributed on four soil series at elevations ranging from 150 to 850 meters. Phosphorus and sulfur were applied separately and together at each site which had been seeded to subclover. Non-legumes volunteered abundantly. Step-wise multiple regression analysis was used to compare site characteristics with yields. All sites responded to P alone, 44% responded to S alone, and 80% responded to S when P was applied. When check plot yields were compared, $NaHCO_3$-extractable P was the most important site variable. When yields from P + S treated plots were compared, exchangeable K was the variable most highly related to yield followed by Mg. The correlation was positive for K and negative for Mg. Ridge regression analysis was used to test which of the intercorrelated variables were truly stable.

4122. Jones, Milton B. 1979. **Plant responses to sulfur in western United States (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 222.
Abstract: Plant responses to sulfur in states west of the Missouri River have been reported on a wide range of crops in the field including forage legumes and grasses, cereals, citrus, deciduous fruits, vegetables and conifers. Legumes have responded to applications of sulfur alone, or to sulfur when P requirements are met. Non-legumes often give a secondary response to S when adequate levels of N and P have been applied. Responses to S-containing fertilizer s are widespread in parts of California, Oregon, Washington, northern Idaho, and western Montana. There has been little if any response to S in Nevada, Utah, Arizona, Wyoming, Colorado, and New Mexico, while some responses have been reported in the Great Plains states. Responses to S fertilization are dependent upon the crop, available soil S, the amount of S in the rainwater, irrigation water, atmosphere, and other additions in connection with agricultural practices. Sulfur in rain and the atmosphere is generally lowest along the west coast and increases toward the east. It tends to be higher near cities than in the country. Sulfur in irrigation water is usually lowest in the headwaters and increases downstream. If sulfur supplied from all these sources is high enough to supply crop needs, there will be no response to applied sulfur.

4123. Jones, Milton B., and R. G. Woodmansee. 1979. **Biogeochemical cycling in annual grassland ecosystems.** The Botanical Review 45(2):111-144.
Abstract: Nitrogen, phosphorus, and sulfur are essential nutrients for the maintenance of annual grassland ecosystems because they are important elements in the synthesis of organic matter. Many other elements are also essential, but they were not included here because little information about their cycling is available. Nitrogen occurs primarily in organic forms in ecosystems, but most of it is bound in very slowly cycling forms. Most N used by organisms is mineralized from plant residues of the previous growing season. The N cycle is open, meaning that significant amounts of the element may be added to the ecosystem from natural external sources: as NH_4^+ and NO_3^- from the atmosphere and as N_2 from fixation by plants. However, significant amounts of N may be lost from the system by leaching, volatilization of NH_3, and denitrification. Nitrogen plans a very important role in ecosystem functioning and can be manipulated by fertilization or legume management. Phosphorus occurs in both organic and inorganic forms. As with N, organic forms occur in both slowly cycling and fast-cycling forms. The fast-cycling forms are very important sources of P for organisms, especially in ecosystems where it is in short supply. In addition to the organic forms of P, a labile inorganic pool can be very important. In some ecosystems this pool is sufficiently large to supply adequate amounts of P for plant

growth, while in other systems it is small and P can limit vegetation production. In some systems P can stimulate legume development, thereby improving the N status of the community. The P cycle is relatively closed, compared to the N cycle, and natural additions and losses are very small. Where P is in limited supply, fertilization can be beneficial. As with N, sulfur occurs principally in organic forms and its cycling properties are generally similar to those of N. The "openness" of the S cycle is probably intermediate between N and P. Plant production responds to addition of S in many ecosystems. The response may be caused by amelioration of S deficiencies in many types of plants of the ecosystem, or the S may stimulate legume production, resulting in increased N production.

Guy E. Connolly

Range drill and bulldozer used in seeding for improved pasture, October 1972

4124. Jones, Milton B., Robert L. Koenigs, Charles E. Vaughn, and Alfred H. Murphy. 1980. **Long-term effects of brush control treatments on soil fertility (Abstract).** Pp. 46-47 *in:* Proc. 61st Annual Meeting, Pac. Div. Am. Assoc. for the Adv. of Sci., Davis, CA, Jun. 22-27.
Abstract: In 1956 chaparral growing on Los Gatos soil (fine-loamy, mixed mesic family of typic argixerolls) was crushed and burned. Half of the burn was fenced to exclude herbivores after it had been seeded to grasses and clovers. Sprouting brush was treated periodically as follows: 1) burning, 2) herbicides, and 3) no follow-up treatments. Twenty-two years after the initial burn there was about 3% brush cover on reburned plots, virtually none where herbicides were used, and nearly 100% ground cover was brush in the control. Herbaceous plants were abundant where brush sprouts had been controlled. Soil samples taken from the six areas indicated that where brush was controlled and plots were grazed the availability of N, P, S, K, Ca, and Mg was much greater than where brush regrew. Comparing the same treatments on the ungrazed plots there were differences in nutrient availability, but they were smaller than on the grazed plots. It was concluded that nutrient availability increased over the 22-year period on a brush soil converted to grassland and this increase in fertility was enhanced by grazing animals.

4125. Jones, Milton B., V. V. Rendig, Donald T. Torell, and T. S. Inouye. 1980. **Quality of forage for sheep as related to various levels of sulfur (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 125.
Abstract: This study measured the response of lambs fed forage having a range of S concentrations. Five rates of S were applied to S-deficient subclover-grass and to ryegrass pastures. The ryegrass was fertilized with N, and both pasture types received P and K. The forage was harvested as hay, ground, pelleted, and fed to lambs. The experiment was repeated twice with about 80 lambs each time. Total S in both grass and clover ranged from 0.10% to 0.22%. There was high correlation between plant S and sulfate-S levels in the blood with R^2's of 0.75 and 0.90 for total plant S versus blood sulfate, respectively. The average gains of lambs fed clover from plots fertilized with S was 177 g/day compared to 118 g/day for those fed unfertilized clover hay for 63 days. Ryegrass produced much smaller gains ranging from 17 g/day for the controls to a maximum of 83 g/day for lambs fed the S fertilized grass hay. It was concluded that on a S-deficient site, increasing the forage S levels by fertilization increased forage quality as reflected by rate of gain, field efficiency, and chemical composition. The possibility of utilizing the sulfate-S blood level of sheep to assay the S status of a pasture is suggested.

4126. Jones, Milton B., J. E. Ruckman, William A. Williams, and Robert L. Koenigs. 1980. **Sulfur diagnostic criteria as affected by age and defoliation of subclover.** Agron. J. 72:1043-1046.
Abstract: Sulfur deficiencies are widespread in California annual grasslands and in other areas of the world where subclover (*Trifolium subterraneum*) is an important legume. Intensive grazing is often practiced where subclover is grown. Therefore, to determine the need for S fertilization, it is important to know how defoliation and plant age influence the diagnostic tissue tests used to assay subclover S status. Subclover was grown on S-deficient soil (Josephine, fine-loamy, mixed mesic, Typic Haplozerults) with six levels of applied S and four clipping treatments in a greenhouse. Four criteria for assaying S status were used: total S, sulfate S, sulfate S/total S ratio, and N/S ratio in the three youngest fully expanded leaves required to give 90% of maximum yield (critical levels based on Mitscherlich functions). The critical levels of sulfate S/total S and N/S ratios were the most stable over plant age and clipping frequency. Both assays accounted for about three-quarters of the variation on the average. The critical levels of total S and sulfate S although associated with over 90% of the variation were not stable individually, decreasing from 0.20 to 0.08% S and from 220 to 140 ppm sulfate S at 60 and 133 days from planting, respectively. Clipping frequency caused considerable variation in the critical levels for total S and sulfate S assays, making them more difficult to interpret than the sulfate S/total S and N/S ratio assays. It was concluded that the sulfate S/total S ratio has some advantages over the other assays, such as stability through the growing season, being little affected by defoliation, and resulting from a single analytical regime.

4127. Jones, Milton B., William A. Williams, and Charles E. Vaughn. 1981. **Mineral nutrient concentration ratios in annual grassland forage: a means of assaying nutrient status (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 180.
Abstract: On the annual grasslands of California, soil analysis has been useful in assaying the availability of P and K as related to pasture productivity. While soil tests have been of little value in determining the S status of the same soils, the S status can be determined by plant analysis. Some of the limitations for plant analysis are that stage of growth, plant part, and intensity of grazing influence the critical levels. Multinutrient deficiencies and interactions also make plant analysis difficult to interpret. The Diagnosis and Recommendation Integrated Systems (DRIS) has been suggested as a means of overcoming many of these disadvantages. The ratios of concentrations of the following elements in pasture forage were determined: P, K, S, Ca, and Mg. These ratios were compared to norms obtained from high yielding plots to determine which nutrients were most limiting, adequate, or abundant. When this method was applied to a series of pasture sites, the results were consistent with yield response to P and S fertilization with soil and plant analysis.

4128. Jones, Milton B., V. V. Rendig, Donald T. Torell, and T. S. Inouye. 1982. **Forage quality for sheep and chemical**

composition associated with sulfur fertilization on a sulfur deficient site. Agron. J. 74:775-780.
Abstract: Improvements in forage quality and yield have resulted from application of S fertilizer. The purpose of this study was to relate forage composition changes associated with S fertilization to quality, as measured by lamb growth, efficiency of feed eaten by lambs, in vitro digestibility, and blood serum sulfate levels. Five rates of S were applied on a Sutherlin soil series (Ultic Haploxerolls) in each of 2 successive years to two sets of plots, one set seeded to subclover (*Trifolium subterraneum*) (designated "clover-grass"), the other to ryegrass (*Lolium multiflorum*). The ryegrass plots were also fertilized with N, and all plots received applications of P and K. The forage was harvested as hay, ground, pelleted, and fed to lambs in two feeding trials with an average duration of 60 days. Sulfur concentrations ranged from 0.13 to 0.24% in the clover-grass and from 0.09 to 0.22% in ryegrass. Protein ranged from 10.3 to 13.1% in the clover-grass, and from 6.3 to 8.0% in the ryegrass. The N/S ratios ranged from 8 to 13 for the clover-grass and from 6 to 13 for ryegrass. Application of S to the soil increased the average daily grains (ADG) of lambs for the two trials, from 141 to 186 g for the clover-grass, and from 32 to 84 g for the ryegrass. Ninety percent of the maximum ADG (defined as a critical value) was obtained at 0.19% S in the clover. A critical value is not given for ryegrass since ADG increased with each increment of S added, including the highest level of S applied. This was likely due to N being more limiting than S in the diet of the lambs. Blood serum sulfate-S in the lambs was more closely related to % S in clover-grass forage (r^2 = 0.76) than to % S in ryegrass (r^2 = 0.50). A good relationship (r^2 = 0.90) was found between serum sulfate-S level and sulfate-S intake for both forages. Blood sulfate was related to growth rate of lambs by a negative exponential function, with estimated critical values of 30 and 39 μg/ml, respectively, for the ryegrass and the clover-grass hay pellets. An average of 11 kg feed/kg gain was required for sheep on clover-grass with zero S applied. This dropped to 9 kg feed/kg gain where S was applied. On ryegrass this ratio was 48 on the zero-S treatment, but it dropped to an average of 18 with S applied.

4129. Jones, Milton B. 1983. **Fertilizing subclover-grass pastures.** Better Crops with Plant Food 67 (Spring 1983):28-29, 31.
Abstract: California's annual grasslands are characterized by low production during winter, rapid spring growth, and low forage quality during the dry summer and fall. These grasslands are very deficient in N and are often deficient in P and S. Responses to K, Mo, and Ca have been reported but are not so widespread. High rainfall zones (received in excess of 30 inches) are well adapted to seeding with subclover, which maintains a high level of forage protein during the dry season. Data on botanical composition, yield, and protein level of a grazed pasture are given as affected by subclover and N fertilization. Soil tests for S are not very reliable for California grasslands; plant analysis for total S or sulfate S can be useful if done during rapid spring growth. Little work on potassium has been done on California grasslands. Recommendations for Oregon appear to apply here; where soil test values are over 150 ppm exchangeable K, no K fertilizer should be applied. There are some grassland soils in California derived from serpentine that are high in Mg and low in Ca that will respond to Ca as a nutrient. Our results clearly show that the production potential and forage quality of California grasslands in areas of >25 inches of rainfall can be greatly increased by seeding subclover and fertilizing with P, S. and other nutrients.

4130. Jones, Milton B. 1983. **Integrating multiple factors in interpreting tissue analysis results.** Pp. 113-114 *in:* Proc. Calif. Plant and Soil Conf.
Abstract: This discussion compares the Crop Log system, a critical concentration approach for diagnosing nutrient status of crops, to the DRIS (Diagnosis and Recommendation Integrated System). DRIS provides a method of considering a number of mineral nutrient concentration ratios simultaneously, thus more easily and reliably identifying the nutrient(s) that limit yield. Preliminary data from subclover pastures in California indicate the DRIS approach to be promising. Further work will be required to establish ratio norms and coefficients of variation.

4131. Jones, Milton B., Robert L. Koenigs, Charles E. Vaughn, and Alfred H. Murphy. 1983. **Converting chaparral to grassland increases soil fertility.** Calif. Agric. 37(9-10):23-24.
Abstract: This study compared the long-term effects of chaparral conversion and chaparral regrowth, with and without grazing, on the availability of soil nutrients. When soil cover was converted from brush to grassland, seeded to annual grasses and clovers, and grazed by herbivores for 23 years, available soil nutrients were higher than in comparable soil where grassland species were not grazed or where the cover type reverted back to the original brush. Nitrogen increased most, but available P and S also increased. Calcium, Mg, and K were also taken up in greater amounts from grazed grass-covered soils than from brush-covered soils. Several factors may account for such increases in soil fertility. Crushing and burning brush immediately increases availability of soil nutrients, which are held in surface soils by the shallow fibrous root systems of grassland plants. Grazing increases the rate of nutrient cycling and may increase nutrient availability. Grazing resulted in a large increase in legumes, and thus in additional N fixation and available N. Finally, brush soils have virtually no herbaceous ground cover beneath the brush, and erosion is often clearly available; such an environment is not conducive to holding nutrients or to soil formation.

4132. Jones, Milton B., Robert L. Koenigs, Charles E. Vaughn, and Alfred H. Murphy. 1983. **Effect of converting chaparral to grassland on soil fertility in a Mediterranean type climate.** Pp. 291-293 *in:* Proc. XIV Int. Grassland Congr., Lexington, KY. Westview Press, Boulder, CO.
Abstract: In the region of Mediterranean-type climate in California, brush is converted to grassland to reduce fire hazards, increase feed for herbivores, and increase water yields. There is little information on how this change of cover type affects soil fertility over a long period. Research was initiated to measure the long-term effect of converting brush to grass on availability of nutrients in the soil. In 1956 chaparral growing on Los Gatos soil (fine-loamy, mixed mesic family of argixerolls) was crushed, burned, and seeded to grasses and clovers, and half the area was fenced to exclude herbivores. Sprouting brush either was treated periodically by burning or with herbicides or was not treated at all. Twenty-three years after the initial burn, about 3% of the cover on reburned plots was brush, virtually none was brush where herbicides were used, and nearly 100% was brush where nothing was done to control growth. Herbaceous plants were abundant where brush sprouts had been controlled. Soil samples were taken from the six treatments for chemical analysis and a pot experiment. Soft chess (*Bromus mollis*) was grown in pots fertilized with all combinations of nitrogen (N), phosphorus (P), and sulfur (S). The plants were analyzed for N, P, S, potassium (K), calcium (Ca), and magnesium (Mg). In the pot study, uptake of N, P, K, S, Ca, and Mg was greater from soils where brush regrowth was controlled than from soils where brush had regrown. These differences were much greater for soils under grazing. Extractable nutrients in the soils from the grazed area were also higher from grassland plots than from brush plots. The grazed grassland had 81% groundcover by living plants, of which 14% was annual legumes, 25% annual grasses, 30% *Erodium* spp., and 11% perennial grasses. The ungrazed plots had 25% ground cover and only 3% legumes, 7% annual grasses, 1% *Erodium* spp., and 9% perennial grasses. Nutrient availability was greater after a 23-year period in brush-soil converted to grassland than where brush regrew, and this difference in soil fertility was enhanced by grazing. The difference in soil fertility on the grazed grassland plots may be due

to: 1) the shallower, more fibrous root systems of grassland species (as compared with brush) resulting in retention of mineral nutrients in the surface soil; 2) increased rate of cycling, and thus nutrient availability, due to grazing animals; 3) the contribution of annual legumes to soil N; and 4) a reduction in surface-soil erosion, there being much bare soil and erosion pavement under the brush.

4133. Jones, Milton B., William A. Williams, and Charles E. Vaughn. 1983. **Soil characteristics related to production on subclover-grass range.** J. Range Manage. 36(4):444-446.
Abstract: In northwestern California, moisture is usually not limiting for range production during the annual winter-spring growing season. It is therefore important to understand how other site factors, both physical and chemical, affect range production. Ridge regression analysis and simple correlations were used to evaluate range production as related to site slope and elevation; soil depth, texture, bulk density, water holding capacity, and pH; and several chemical measures of soil fertility including available P and S, exchangeable cations, total N and S, and organic matter. Subclover (*Trifolium subterraneum*)-grass production was measured at 17 typical range sites for 4 fertilizer treatments: P_0S_0, $P_{300}S_0$, P_0S_{90}, $P_{300}S_{90}$, (subscripts = kg/ha). When no fertilizer was applied, soil pH and available P appeared to be the two variables most closely related to yield. Forage production increased when P and S fertilizers were applied. When P was applied, exchangeable soil K was the most important variable related to yield; and when S was applied, available P was the variable most closely related to production. When P and S were applied together, available P and K were most closely related to yield. While there was generally a striking response to applied S, our measures of available soil S were poorly related to production.

4134. Jones, Milton B. 1984. **Effects of fertilizer sources of sulfur on plant growth and sulfur uptake.** Pp. 711-716 *in:* Proc. Sulfur-84 Int. Conf., Sulfur Dev. Inst. of Canada, Calgary, Alberta.
Abstract: There are many sulfur-containing fertilizers on the market today. They have been placed in three groups based on the chemical form of S: those containing elemental S, sulphate S, and other forms. This review paper was limited to a discussion of elemental and sulphate S and the conditions that affect their availability to plants. Since S is absorbed by the plant roots as sulphate, those fertilizers that contain soluble sulphate compounds are readily available so long as the sulphate remains in the root zone. Sulphate is easily leached from the soil, and the extent of leaching loss depends on rainfall, sulphate retention ability of the soil, and drainage properties. The availability of elemental S is dependent upon the presence of S-oxidizing bacteria. Bacterial oxidation rates are, in turn, dependent upon such factors as S particle size, rate of application, soil pH, temperature, water content, and organic matter content. The comparative value of sulphate S compared to elemental S-containing fertilizers depends on several factors. In general, in warmer and wetter climates elemental-S with fine particle size is recommended.

4135. Jones, Milton B. 1984. **Effects of sulfur fertilization on the quality of forage for sheep.** Pp. 747-752 *in:* Proc. Sulfur-84 Int. Conf., Sulfur Dev. Inst. of Canada, Calgary, Alberta.
Abstract: Sulfur deficiencies are widespread on the annual grasslands of northern and central California and Oregon. When the availability of other nutrients is adequate, the forage yield response to S fertilization is often very dramatic and the quality of the forage is improved as well. The effect can be classified as primary (in this case simply increasing the level of S in forage) or secondary (modifications in the chemical and botanical composition of the forage). The primary effects of S deficiency result when the level in the diet is lower than the requirements of the rumen microorganisms. Activity in the rumen is then depressed which results in lower feed intake and rates of gain. Increasing S levels in forage results in increases in both digestibility and feed intake, often as a result of increasing forage leafiness. The main secondary effect on forage chemical composition resulting from increasing S levels are increases in chlorophyll, vitamin A, protein, methionine, cystine, and soluble sugars. Sulfur has complex interactions with other elements, mainly selenium, copper, and molybdenum, which can also have an important secondary effect on ruminant nutrition. Botanical composition changes are important to forage quality, and S fertilization can change the percentages of various species competing with each other. Legume growth in enhanced by S additions, apparently because of their higher requirements for available S than grasses. If soil S levels are kept adequate for legume growth by repeated fertilization, and if grazing management keeps grass competition down, then legume stands can persist.

4136. Jones, Milton B., D. Michael Center, Charles E. Vaughn, Martin R. Dally, and Montague W. Demment. 1985. **Effect of P and S fertilization of annual grassland pasture on lamb production (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 175.
Abstract: The almost universal deficiency of N on California annual grasslands can be ameliorated by legumes such as subclover if they are adequately supplied with P and S. The objective of this study was to measure the effect of P and S fertilization of subclover pasture on lamb gains per head and lamb gains per acre, and to relate these gains to the chemical constituents of the forage. Lambs were weaned at about three months of age, weighing 18 kg, and were placed on 16 one acre pastures which had been fertilized with 4 levels of P (0 to 56 kg/ha) and two levels of S (0 and 98 kg/ha) replicated twice. The number of lambs in each pasture was proportional to the amount of forage on offer. The trial was repeated for three years. Lambs gained 2.0 kg more in 84 days where S was applied compared to no S. Fertilization with P made no difference (>.05) in rate of lamb gain. Both P and S each increased lamb gains an average of 123 kg/ha/year. The relationship of forage N, P, and S concentrations to lamb gains/head and per ha and blood S and Se levels will be discussed.

4137. Jones, Milton B. 1986. **Sulfur availability indexes.** Pp. 549-566 *in*: Sulfur in Agriculture, Agronomy Monogr. 27. Am. Soc. Agron., Madison, WI.
Abstract: Assays of soil and plant S are frequently used to evaluate the S status of crops. The various techniques useful for diagnosing S deficiencies on plants are discussed, with examples of each technique cited. The need to assay the S status of crops and soils is important now and will become more so as we press for high production. Plant and soil analysis will be useful in helping to meet high production goals if farmers, their advisors, and suppliers understand how to use them. For plant analysis, this understanding consists of obtaining a representative sample of a given plant part, at a consistent stage of growth (previously calibrated) and knowing which chemical analysis to run (total S, SO^2_4 -S, or both if the total S/SO^2_4 -S ratio is to be used, and N if N/S ratio is desired). The status of other essential mineral nutrients and factors that effect crop growth should also be known. Soil analysis appears to be more useful in some areas of the world than others. Wherever it is used, knowledge is needed of soil properties, environmental conditions, and the management history of the fields in question in order to make proper use of soil information.

4138. Jones, Milton B., D. Michael Center, Montague W. Demment, Martin R. Dally, Charles E. Vaughn, and William A. Williams. 1986. **Lamb gains improve on pastures fertilized with phosphorus and sulfur.** Better Crops with Plant Food 70:8-9.
Abstract: This study was established with the goal of maximizing lamb production on annual-type grasslands. The N requirements were supplied by seeding 50 lb/a of subclover on a 16-acre site which had been prepared by burning the old dry grass and disking. Treatments were four levels of P, with and without S. Each of the 8

treatments was applied to one acre with two replications. This study shows the potential some of our annual grasslands have for lamb production when intensively managed. The amount of lamb produced per acre in this study is 5 to 10 times greater than production on some of our other pastures, because in this study all of the pasture growth, except that needed for mulch (about 900 lb/a), was utilized exclusively for lamb growth. Subclover pastures can be grazed sufficiently during winter months to keep down grass competition and maintain clover stands. Then, if the production during winter and spring can be converted into saleable products such as lamb, the P and S fertilization will be profitable.

4139. Jones, Milton B., D. Michael Center, Charles E. Vaughn, and Fremont L. Bell. 1986. **Using DRIS to assay nutrients in subclover.** Calif. Agric. 40(9-10):19-21.
Abstract: The Diagnosis and Recommendation Integrated System (DRIS) appears to work reasonably well in diagnosing the phosphorus and sulfur status of subclover under field conditions, but the nitrogen and calcium indices do not appear to be very useful. On a soil where the DRIS potassium index of the unfertilized treatment indicated adequate potassium, there was no yield response to applied potassium, but the value of the potassium index increased. Further testing on potassium-responsive soils will be required to establish usefulness of the index. The usefulness of the magnesium levels also awaits further research.

4140. Jones, Milton B. 1987. **DRIS as a diagnostic tool for assessing crop nutrient status – California studies.** Pp. 61-64 *in:* Proc. Calif. Plant and Soil Conf.
Abstract: Procedures for diagnosing the nutrient status of crops by tissue analysis generally require the sampling of particular plant parts at particular stages of development under given environmental and management conditions. The Diagnosis and Recommendation Integrated System (DRIS) assesses nutrient status of crop and forage plants by comparing ratios of important nutrient element concentrations in the tissue being assayed with the same ratios (reference norms) from high producing crops. DRIS is a useful tool in diagnosing the P and S status of subclover under field conditions. The K DRIS index also appears to be accurate, but more K-responsive sites growing subclover are being tested. The percentage of Ca and Mg did not decrease with subclover maturity in our studies. Assaying the status of these two elements on subclover with DRIS does not seem promising.

4141. Jones, Milton B. 1987. **Pasture improvement and its effect on sheep production.** Pp. 11-13 *in:* Proc. Sheep Breeding School, Hopland, CA. Hopland Field Station, Univ. Calif.
Abstract: Soils in northern California's annual pastures are generally very deficient in nitrogen, phosphorus, and sulfur. Nitrogen fertilizers are expensive and their benefits are short lived. Subclover stands, when heavily grazed in fall, winter, and early spring and moderately grazed in late spring, will perpetuate themselves indefinitely. If these stands are adequately supplied with phosphorus and sulfur, pasture nitrogen and animal protein needs will be enhanced. Selenium given to lambs on these fertilized subclover pastures increased their rate of growth, and preliminary indications are that selenium given to breeding ewes grazing these pastures will increase the number of lambs born.

4142. Jones, Milton B., D. Michael Center, Victor V. Rendig, Martin R. Dally, Ben B. Norman, and William A. Williams. 1987. **Selenium enhances lamb gains on sulfur-fertilized pasture.** Calif. Agric. 41(5-6):14-16.
Abstract: The Sutherlin soil series (ultic haploxerolls) is one of many California annual range soils that are often deficient in sulfur, and large responses to sulfur can occur if nitrogen is supplied by either legumes or fertilization. The objective of this study was to determine the effects of the sulfur level in pasture forage on lamb gains, and to relate these gains to forage sulfur and to blood sulfur and selenium. Sulfur fertilization increased forage production and sulfur concentration in the forage (and nitrogen in subclover-grass forage). Applied sulfur also increased blood-serum reducible sulfur levels but decreased blood selenium in lambs. Gains per lamb were greater on sulfur-fertilized pasture when other factors such as low selenium, low nitrogen, or heavy parasite load did not limit growth. On sulfur fertilized pastures, lambs that were not given selenium boluses had blood selenium levels below 0.05 μg/ml, which is considered the minimum for lamb health. Lambs on unfertilized pastures had blood selenium values above the minimum. Treating the lambs with selenium increased gains on sulfur fertilized pasture.

4143. Jones, Milton B., D. Michael Center, and Charles E. Vaughn. 1987. **Data base size for DRIS norms on subclover type pasture (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 206.
Abstract: The objectives of this study were to determine the number of observations required for mean nutrient concentrations and ratios to reach stable values, and to determine the standard DRIS (Diagnosis and Recommendation Integrated System) norm values for high yielding subclover (*Trifolium subterraneum*) pasture. Nearly 700 observations were made on subclover fertilizer plots over a wide geographic area of northern California. The plots had variable rates of phosphorus, potassium, and sulfur applied. Yields were estimated by clipping, and subclover leaves were sampled on at least two dates. Nitrogen, P, S, K, Ca, and Mg concentrations in the leaves were determined. All the observations were randomized, then mean nutrient concentrations and their ratios were compared in groups of 50. The mean values stabilized with about 200 random observations, which appears to be about the minimum number required to obtain norm values on this data set. Standard normal ratios of nutrient concentrations are proposed.

4144. Jones, Milton B., Martin R. Dally, D. Michael Center, Victor V. Rendig, and Ben B. Norman. 1987. **Production and lamb growth response to sulfur fertilization and selenium treatment on California annual type pastures.** SID Res. Digest 4(1):4-8.
Abstract: Lambs were grazed on pastures fertilized with rates of sulfur (S) varying from 0 to 80 lb/year. Two pasture types were used; subclover-grass, and nitrogen (N)-fertilized ryegrass. The 4-year average gain of lambs on S fertilized subclover pasture was 49 lb compared to 40 lb with no S, 39 lb for lambs on N-grass plus S, and 37 lb for lambs on N fertilized grass with no S. Blood tests indicated that lambs on high S pastures had levels of selenium (Se) below the recommended minimum level of 0.05 μg/ml. In the fourth year of the study, half of early weaned lambs (45 lb) were supplemented with Se. The Se-supplemented lambs on high S subclover pasture gained 47 lb compared to 44 lb with no Se. The values for lamb gain on the N-grass were 36 and 30 lb, respectively. Gains per acre on subclover-grass were 273, 272, 405, and 438 lb for no S and no Se, no S plus Se, plus S no Se, and plus S plus Se treatments, respectively. Gains per acre on N-grass for the respective treatments were 256, 241, 350, and 412 lb. The average forage production from subclover-grass pastures was 3,860 and 5,740 lb/a from the respective no S and plus S treatments, while N-grass yielded 5,670 and 7,610 lb/a respectively. Even though much more forage was produced on the N-grass pasture than on the subclover, the clover produced as much lamb per acre as the N-grass, indicating the high quality of the subclover-grass forage. The quality of both forage types was enhanced by S fertilization and Se supplementation.

4145. Jones, Milton B., and Charles E. Vaughn. 1987. **Response of seeded annual grasses and clovers to fertilization on a serpentine site.** Range Sci. Rep. 11, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 10 pp.
Abstract: The establishment of herbaceous vegetation on soil

derived from parent material of peridotite-serpentine rock is important to reduce erosion on sites cleared for roads, mining, drilling, or for increased forage production. The natural vegetation includes shrubs and stunted trees with little or no herbaceous ground cover. The soils are characteristically deficient in N, P, K, Ca, and Mo, as well as being gravelly and shallow to parent material. Other problems include a high Mg content and possible toxicities of Ni and Cr. Previous studies showed that subclover grown on potted serpentine soils taken from 23 sites in Lake and Napa counties responded to P and S applications on all of the soils; there were also 17 yield responses to Ca, 10 to K, and 14 to Mo. The present study was done to determine the field response of seeded grasses and clovers to fertilization with macro- and micronutrients at one of the 23 serpentine soil sites. The Henneke soil was extremely deficient in N and P, and somewhat deficient in K and S. The N concentration in the clover indicated a significant response to Mo. Residual yield responses to N were negative. This was related to the reduction in clover where N was applied which reduced N fixation and, thus, yields in subsequent years. When N, P, K, and S were applied, forage yields ranged from 4,500 to 5,500 kg/ha. Without applied N, highest forage production was 2,500 kg/ha after the clover was well established and contributing N to the soil. A single application of 112 kg P/ha had the effect of doubling yields through the seventh year after application when the study was discontinued.

Visitors from China are accompanied on field tour by agronomist Milton Jones (right) and superintendent Bob Timm (left), November 1987

4146. Jones, Milton B., Montague W. Demment, Martin R. Dally, and Charles E. Vaughn. 1988. **Lamb gain response to phosphorus and sulfur fertilized subclover-grass pasture (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 239.
Abstract: The objectives of this study were to measure the effect of P and S fertilization of subclover (*Trifolium subterraneum*) pasture on average daily gain (ADG) and lamb gain/ha, and to relate these gains to the botanical and chemical constituents of the forage. Lambs weighing 20 kg were weaned and set stocked at a constant herbage allowance (kg forage/lamb) across four P and two S levels during March, April and May. In the first 3 years the mean ADG/year was 196, 200, 219, and 223 kg for the CK (control), P, S and PS treatments, respectively. For the final 3 three years there were no treatment differences. However, ADG was highly correlated with forage neutral detergent fiber (NDF), g/kg N, g/kg S and percent clover in all years. The NDF had the most direct effect on ADG. The 6-year mean lamb gain/ha values were 244, 380, 405, and 435 kg for the CK, P, S, and PS treatments, respectively. The lamb gain/ha was most closely related to the quantity of forage on offer. It was concluded that P-S fertilization increased lamb production by increasing the quantity and quality of the forage on offer, and that subclover played a vital role in both factors.

4147. Jones, Milton B., and William H. Brooks. 1989. **Subclover responds negatively to applied nitrogen when competing with annual grasses.** Range Sci. Rep. 27, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 8 pp.
Abstract: Nitrogen is sometimes applied to subclover-grass (*Trifolium subterraneum*) pastures in northern California and Oregon to increase herbage growth in winter, or on new seedlings where soils are very low in available N. The objectives of these studies were: 1) to measure the effect of applied N on subclover yield when grown alone and with competing grass on a pot study; and 2) to measure the effect of N on seedling survival and forage production into the second year under field conditions. In the pot study where subclover was grown without competition, it did not respond to 5 ppm N but did respond to 10 and 20 ppm rates. Higher levels gave no additional growth. However, where subclover and grass were sown together, the grass responded linearly up 60 ppm N, but subclover yields were unchanged or depressed by any applied N. In the field, the number of seedlings that survived until spring was depressed by applied N, and in the second year total forage yields were higher with applied PS than with NPS. The percent subclover in the stand was also depressed the second growing season. Since it has been shown that 5,600 lb/a of subclover-grass pasture produced as much lamb/a as 8,000 lb/a of ryegrass, and that lamb growth rates are positively correlated with the percentage of subclover in a pasture, it appears counter-productive to use N on subclover.

4148. Jones, Milton B., Montague W. Demment, Martin R. Dally, and Charles E. Vaughn. 1990. **Subclover-seeded, fertilized pasture for early weaned lambs.** Calif. Agric. 44(5):38-41.
Abstract: A 6-year grazing study on subclover pasture at Hopland indicated that lambs weaned at 40 pounds made excellent gains. Phosphorus and sulfur fertilization enhanced the gains enough to be profitable. By concentrating lambs on highly productive, well-protected pastures, researchers not only used inputs more efficiently, they also prevented many of the predator losses encountered in nearby, less-protected pastures.

4149. Jones, Milton B., and A. G. Sinclair. 1990. **Use of the Diagnosis and Recommendation Integrated System (DRIS) on New Zealand white clover pastures.** Invermay Agricultural Centre, Ministry of Agriculture & Fisheries, Mosgiel, New Zealand. 40 pp.
Abstract: DRIS is a method of interpreting herbage chemical analysis. It assesses the nutritional status of plants from a consideration of the ratios of nutrient concentrations in the plants rather than from individual concentrations in isolation. A major advantage claimed for DRIS is its ability to rank plant nutrients in order of relative deficiency/adequacy. It may also be used to assess whether or not individual elements are deficient. This work was undertaken to evaluate DRIS for white clover-based pastures in New Zealand. DRIS was tested using chemical analysis of the clover component of pasture samples from high country and lowland fertilizer trials in the South Island. The relative deficiencies of P and S in these trials were assessed from a combination of the dry matter (DM) response data and the fertilizer treatments. Relative deficiencies were also assessed independently by DRIS. In 79% of cases, the rankings of P and S deficiency by the two methods were the same. Some of the mis-rankings may be attributable to high variability in DM response rather than to DRIS. DRIS was also tested for its ability to identify absolute deficiencies of individual elements. DRIS and straight nutrient concentrations were about equally successful at differentiating between deficiency and adequacy. However, with nutrient concentrations, the critical levels for best differentiation in lowland pastures were twice as great as those in upland pastures. This problem of variable standards was largely avoided by the use of DRIS in its simplest form in which only

ratios are considered. The same DRIS standards were found to apply to both high country and lowland pastures. In some cases this form of DRIS may not distinguish between plants high and low in nutrients which have the same ratios of nutrients. A variant of DRIS which does make such distinctions by incorporation nutrient concentrations as well as ratios was also assessed. The disadvantage with this form of DRIS was that critical levels for identifying nutrient deficiencies were dependent on the environment under which the plants were grown, although to a lesser extent than with nutrient concentrations alone. DRIS appears to have considerable potential for identifying the most deficient element in a pasture. DRIS encounters difficulties in distinguishing between adequacy and deficiency where samples come from different environments, but these are probably less severe than encountered by nutrient concentrations alone. There are many variants of DRIS, only some of which have been explored in this study. Nevertheless, the results achieved are considered to justify the adoption of DRIS as an aid to the interpretation of clover herbage analysis for assessing plant nutritional status.

4150. Jones, Milton B. 1991. **Forage management for sheep at the University of California Hopland Field Station.** Pp. 15-25 *in:* Proc. Third Int. Meadow Symposium, E. G. Siemer (ed.), Colorado State Univ., Fort Collins, CO.
Abstract: The Mediterranean climate of California's north coastal mountains represented by the Hopland Field Station offers the potential for high pasture productivity by the establishment of annual legumes and productive grasses. The soils are deficient in nitrogen, phosphorus, and sulfur, and these elements must be increased if high productivity is to be achieved. Nitrogen may be supplied through fertilization or by clover nitrogen-fixation. Nitrogen fertilization stimulates grass growth, and is especially good for increasing winter feed. However, since the vigorous grass suppresses the clover, N fertilization of clover stands is not recommended. Good stands of subterranean clover fertilized with P and S have contributed from 50 to 200 lbs N/acre per year, and this can stimulate winter grass growth the following years. The subclover based pastures are of much higher quality than N fertilized grass as shown by more rapid lamb gains on clover pastures than on N fertilized grass. Concentrating lambs on productive subclover pastures makes it possible to give them greater protection from coyotes by more secure fencing and closer monitoring. The subclover also makes excellent summer dry feed, and can be used for flushing ewes prior to and during breeding.

4151. Jones, Milton B., and A. G. Sinclair. 1991. **Application of DRIS to white clover based pastures.** Commun. Soil Sci. Plant Anal. 22(17-18):1895-1918.
Abstract: There are basically two approaches for interpreting chemical analysis of plant tissue to assess nutrient status and fertilizer need. The oldest, called the critical value method (CVM), is based on nutrient concentrations in the sample compared with levels required for near maximum growth. The other is based on the ratios of nutrient concentrations. The Diagnosis and Recommendation Integrated System (DRIS) is a system that uses nutrient ratios, comparing these with norms which are ideal ratios derived from high yielding plants. DRIS integrates the ratios to give an index for each nutrient considered and ranks them in the order of deficiencies. It is helpful in dealing with multiple deficiencies. The DRIS system has not previously been tested on white clover (*Trifolium repens*) based pasture in New Zealand. The purpose of this study was to develop N, S, P, K, and Ca DRIS norms for white clover; to use these norms in computing DRIS indices for clover samples from fertilizer trials; to compare the diagnosis of the S and P status of clover samples with CVM and DRIS; and to compare deficiency rankings of S and P by DRIS with DM responses to S and P fertilization. Norms for high country and lowlands were based on mean clover nutrient contents in high yielding plots in field trials, using plots which gave >90% of maximum yield (95 out of 996 high country samples and 338 out of 1597 lowland samples). The lowland norms of N, S, P, and K concentrations ranged from 18% to 32% higher than concentration norms for high country, whereas differences in the ratios of these elements varied from only three to nine percent. The Ca concentrations were similar for high country and lowlands. Critical nutrient concentrations selected to give best differentiation between deficiency and adequacy of S and P were twice as great in the lowland trial as in the high country trial. This problem of variable criteria was greatly reduced by the use of DRIS when indices were calculated for N, S, and P ratios only. With either set of norms the critical index values separating deficient and adequate samples were close to zero for both P and S. Including more variable such as K and nutrient concentrations in the DRIS equations gave a wider spread in critical index values thus making the diagnosis more restricted to conditions from which norms were derived. It was concluded that the adoption of DRIS as an aid in interpreting white clover plant analysis data would be helpful, especially in ranking S and P deficiencies, and in making recommendations for applying S and P in proportions best related to plant needs.

4152. Jones, Milton B., Charles E. Vaughn, and William A. Williams. 1995. **Soil phosphorus requirements for maximum growth of northern California subclover-annual grass pastures.** Commun. Soil Sci. Plant Anal. 26(1-2):197-207.
Abstract: Annual grassland soils of California are generally quite deficient in phosphorus (P), but the amount of fertilizer P required to obtain optimum pasture production is quite variable. This paper reports on the relationships between five soil-P tests and the amount of applied P required to obtain near maximum growth of subclover-grass pasture on 12 sites representing four soil series in the north coastal range of California. Dry matter (DM) yield response curves resulting from application of nine levels of P were fitted to the Mitscherlich equation: y = a{1-b([EXP(-cx)]}, where: y = DM when x = kg/ha of P were applied, a = maximum DM when P was not limiting, and b and c are constants that were adjusted to give the best fitting curves by an iterative algorithm. This equation was used to calculate the amount of P required to bring yields to 90% of the maximum DM represented by "a" in the equation. Then the regression equations relating P requirements to soil-P extracted by the Bray-1, Olsen, and modified Olsen methods, and P sorbed by the soils in 17 hours or 6 days were computed. Phosphorus sorbed in 17 hours was most closely related to P requirement, followed by Bray-1 P, modified Olsen, and Olsen, respectively. Virtually all the P applied was sorbed by all the soils in 6 days using the Fox-Kamprath method and discrimination among soils on that basis was impossible.

4153. Kay, Burgess L. 1964. **Paraquat - an aid to the seeding and management of rangelands in the Mediterranean climate of California.** *In:* Proc. 7th British Weed Control Conf., Brighton, England, Nov. 26. 4 pp.
Abstract: The herbicide paraquat sprayed at 0.5 lb/acre at the time of seeding hardinggrass (*Phalaris tuberosa*) and subterranean clover (*Trifolium subterraneum*) effectively controlled annual weeds, mostly medusahead (*Elymus caput-medusae*), and resulted in establishment of the seeded species. Paraquat was also shown to remove both annual grasses and broadleaves from established stands of rose clover (*T. hirtum*), subterranean clover, and hardinggrass without permanent damage to these species. If applied early in the growing season, yields were not reduced. Protein content of the remaining forages was increased following spraying or clipping. Repeated clipping had similar effects on weed control and forage quality as spraying with paraquat.

4154. Kay, Burgess L., Alfred H. Murphy, and William H. Brooks. 1967. **Control of Italian thistle (*Carduus pycnocephalus*) with herbicides.** P. 22 *in:* Research Progress Rep., Western Weed

Control Conf., Reno, NV, March 1966. (*Also: in:* Agronomy Notes, Jan. 1967, Dept. of Agron. & Range Sci., Univ. Calif. Davis.)
Abstract: Trials to evaluate the effectiveness of several herbicides in controlling Italian thistle were conducted under field conditions at Hopland. Herbicides tested were butoxyethanol ester of 2,4-D and 2,4,5-T, picloram, paraquat, and silvex. Both timing of application and application rates were examined. Other experiments (unpublished) have shown that spraying green plants with paraquat preserves the protein level and results in their being more palatable in the dry state. As thistles have been known to contain toxic levels of nitrates, samples of Italian thistle in the bloom stage were tested for nitrate. No nitrate nitrogen was found within the limits of the test. The protein content was 11%. Sheep were observed to readily eat Italian thistle in the dry state whether it was "cured" with paraquat or left to mature naturally. Results indicated a 1 lb/acre rate of 2,4-D ester in late April gave best control. Paraquat gave control at ½ lb /acre from winter until May, but it is more expensive and current registrations do not support this use.

4155. Kay, Burgess L. 1968. **Effects of paraquat on yield and composition of a subclover-harding grass pasture.** Weed Sci. 16(1):66-68.
Abstract: Annual grasses were removed by 1,1'-dimethyl-4, 4'-bipyridinium salt (paraquat) from subclover (*Trifolium subterraneum*)-hardinggrass (*Phalaris tuberosa*) pastures with only temporary damage to these species. If sprayed at the recommended time, total forage production was unchanged and forage quality was improved. Species composition of the pasture was improved by all spraying treatments.

4156. Kay, Burgess L., and Richard E. Owen. 1970. **Paraquat for range seeding in cismontane California.** Weed Sci. 18(2):238-244.
Abstract: A technique was developed for seeding rangelands which are too steep or too rocky to seed by current methods. Experiments were done on 10 ranches on the north coast of California and in the foothills surrounding the Sacramento Valley. Hardinggrass (*Phalaris tuberosa*) and subclover (*Trifolium subterraneum*) were established by seeding immediately after spraying the resident vegetation with the herbicide 1,1'-dimethyl-4,4'-bipyridium ion (paraquat). Tested for seeding in sod were single disk, double disk, and hoe type drill openers. The double disk was best adapted to the clay soils most common in the area. A heavy-duty rangeland drill was modified with custom-made, heavy, double openers and equipped with a spray system which sprays either bands or full coverage. The resulting planter will kill weeds, plant seeds, and spread fertilizer any place where a crawler tractor can pull it. Weed-free bands of 6 and 12 inches were compared with full spray coverage. No hardinggrass was established without some weed control. In only 5 of 16 tests over a 5-year period was full spray coverage superior to the 6-inch band. The 12-inch band or full spray may be preferable on shallow soils or soils of low water holding capacity. Spraying helped establish subclover but, unlike with hardinggrass, was not critical. Grazing or mowing during establishment period improved stands of both hardinggrass and subclover. Prolonged weed control made paraquat superior to cultivation by giving better weed control and a firmer seedbed.

4157. Kay, Burgess L., and Donald T. Torell. 1970. **Curing standing range forage with herbicides.** J. Range Manage. 23(1):34-41.
Abstract: Paraquat was very effective as a desiccant to cure standing annual range forage just prior to natural maturing of the plant. Diquat and cacodylic acid were less effective on resident range, but were not tried on subclover or vetch. Desiccation of plants at this growth stage made a standing hay 57 to 68% higher in crude protein for a subclover-grass pasture, 77% higher for a 77% annual grass pasture, and 34% higher on a vetch pasture. Forage palatability is enhanced by treatment. Whether this is due to increased crude protein and phosphorus, decreased crude fiber, or other factors is not known. Lambs grazing on forage treated with paraquat gain more rapidly than lambs grazing on naturally matured forage. Total sheep days per acre, however, were less on treated forage than on untreated because sprayed pastures had fewer total days of growth and therefore less forage production. Also, the lambs probably consume more forage per day, further reducing carrying capacity. No physiological or pathological changes were found in lambs that had grazed paraquat-treated forage. The treated plots varied considerably in botanical composition one year after spraying. Annual grasses were greatly reduced in number, especially if much plant residue was left from the preceding year. When subclover was a dominant plant, its percentage was increased in the following year. Weedy plants invaded the area then subclover density was low. Ground cover was about 25% in the winter following spraying, but increased to 100% by early spring. Chemical composition of plants was similar in mowed plots and sprayed plots. Weedy nuisance plants such as Italian thistle can be converted to palatable nutritious feeds by spraying with paraquat before they mature.

4158. Kay, Burgess L. 1972. **Increasing herbicide selectivity on rangeland with activated charcoal.** Pp. 122-125 *in:* Proc. Calif. Weed Control Conf., Vol. 24, Fresno, CA, Jan. 19.
Abstract: High weed populations (up to 100 plants per square inch) indicate a need for effective weed control in range seeding. Preemergence herbicides have been shown to be effective in controlling range weeds, but residues are a possible hazard to seeded species. Application of a slurry of activated charcoal was tested at UC Davis and at the Hopland and Sierra Foothill Range Field Stations for the possibility of reducing herbicide injury to desirable species. The slurry at 300 lb/acre was applied in a 1-inch-wide band centered over the seeded row, either before or after herbicide application. Planting was done with a double-disk opener on a rangeland drill in rows 24 inches apart. Six herbicides were tested: Atrazine, Simazine, Diuron, Bromacil, Terbacil, and Devlon. Species seeded were perlagrass (*Phalaris tuberosa* var. *hirtiglumis*), rose clover (*Trifolium hirtum*), and subterranean clover (*T. subterraneum*). Weed control required much higher rates on the range than at Davis, which may be due to weed species present. The carbon treatment protected seeded grasses and legumes from a variety of herbicides. A 3½-inch-wide board, placed over the seed row, gave equal or superior protection to the carbon, indicating that a shield could be constructed on the sprayer to protect the planted row and save the cost and effort of applying the carbon. The exact degree of protection from either the carbon or shield could not be determined because of severe frost heaving; the better the weed control, the worse the problem. The resulting stand of seeded species on the checks was often superior to the stand with fair to excellent weed control because of the nurse-crop effect of the partially heaved weeds in the check. Possibilities of utilizing the charcoal technique on the range seem limited.

4159. Kay, Burgess L., and Milton B. Jones. 1972. **Pellet-inoculated legume seeds are OK in hydromulching.** Agronomy Progress Rep. 44, Agric. Exp. Stn., Agric. Ext. Serv., Univ. Calif. Davis. 2 pp.
Abstract: Seeding of roadsides and other critical areas in California is commonly done with the hydromulching technique. A slurry of wood fiber, seed, and fertilizer is sprayed on soils that need stabilization. Many of these seedings could be improved by including a legume in the seed mix. Legumes do well on these sites because they are able to furnish their own nitrogen, though the legume seed must be inoculated with the proper bacteria at planting time. To answer questions about whether the inoculum bacteria are washed off the legume seed during the hydromulching process, a

field trial was conducted at Hopland. It was concluded that pellet-inoculated subclover seed will remain effectively inoculated in a hydromulching slurry if delivery time is limited to 30 minutes or less with a centrifugal pump, and probably longer with a rubber-covered gear pump.

4160. Lancaster, Donald L., Milton B. Jones, J. H. Jones, and J. E. Ruckman. 1971. **Effect of sulfur fertilization of forage species on yield, chemical composition and in vitro rumen microbial activity of sheep.** Agron. J. 63:621-623.
Abstract: Three grasses (*Dactylis glomerata*, *Lolium multiflorum*, and *Sorghum vulgare*) and two legumes (*Trifolium repens* and *Medicago sativa*) were grown in pots on S-deficient soil fertilized with varying levels of S. *In vitro* rumen microbial activity as affected by these forages was measured in terms of total gas production using anaerobic manometric technique. The rumen microbial activity in the grasses increased with increasing S, whereas it decreased with increasing S in legumes. The microbial activity was inversely related to the level of protein in the plants and directly related to soluble carbohydrates.

4161. Laude, Horton M. 1958. **Use of herbicides in competition studies of range vegetation.** Ecology 39(3):537-538.
Abstract: Because herbaceous vegetation on annual range frequently emerges in such extreme density that many plants fail to achieve normal size and vigor, there is interest in knowing the effect of reduced plant numbers on growth of rangeland forage species. It was found that a non-selective foliage contact spray could be applied in early spring during cool weather, when more leaf area of forbs was exposed than of grasses. A dinitro compound (Sinox General) was the herbicide used, at a rate of 2 quarts per acre in 100 gals of water. Most forbs were killed, while grasses were uninjured or at most left with a moderate leaf tip-burn. Plots were treated at the Hopland Field Station and at the San Joaquin Experimental Range on February 2 and 6, 1956, respectively, and plant materials were harvested for evaluation on May 16 and 17. After treatment, the vegetation consisted predominantly of grasses. During the spring, these grasses appeared more vigorous and taller than those in control plots. The weight of grass in treated plots was greater by approx. 100% than in untreated plots. A more extensive trial was conducted at the San Joaquin Experiment Range in 1957, with multiple spray dates from late January through early March. As in the previous year's trials, suppression of forb growth enhanced grass growth and development, with the effect being more pronounced the earlier the herbicide was applied. The results suggest that herbicides may be useful in controlling the density of natural vegetation on rangelands. With increasing selectivity of herbicides, it is conceivable that the competition afforded by a single species may one day be studied through herbicidal removal.

4162. Laude, Horton M., Milton B. Jones, and S. Sherwood Winans. 1959. **Responses of annual range to gibberellic acid.** J. Range Manage. 13(1):10-13.
Abstract: The growth of a mixed stand of herbaceous range species in response to a single foliar spray of gibberellic acid in solution at 100 ppm was studied both in the field and in the greenhouse. The field tests were at two locations on sites fertilized with N alone or N and P. Following spray treatment, plants generally responded by showing a paler green color and a tendency toward greater height. The effect of fall spraying in the field did not persist over winter. In one instance spraying in early March resulted in significant increases in dry weight of herbage when harvested two months later. Though responses to fertilizer were marked, no significant interaction between gibberellic acid and fertilizer was obtained. Species differed in response to the foliar spray and the same species was not consistent in response. In the greenhouse trials, significant increase in dry weight of top growth was obtained with prairie bromegrass (*Bromus catharticus*) but not broadleaf filaree (*Erodium botrys*). The one significant increase in dry weight of herbage obtained in the field was attributed primarily to an increased growth of broadleaf filaree. With our present state of knowledge, the use of gibberellic acid on range to increase forage production does not appear justified. The use of more than a single application is not feasible on such extensive areas, and the likelihood of inducing growth stimulation at the same time on a sizeable proportion of the range flora is remote. As more information is accumulated on gibberellic acid, it is possible that specific uses may be indicated.

4163. Laude, Horton M., Guillermo Riveros, Alfred H. Murphy, and Robert E. Fox. 1968. **Tillering at the reproductive stage in hardinggrass.** J. Range Manage. 21(3):148-151.
Abstract: Depression of tillering near the onset of flowering is characteristic of several perennial grasses. This study was undertaken in an effort to learn whether reduced tillering in perennial grasses is a response to environmental factors, to the reproductive stages of development, or both. For this experiment using hardinggrass (*Phalaris tuberosa*), for comparison at one time both vegetative and reproductive plants were produced through manipulation of daylength and temperature. It was found that reduced tillering at the heading stage is associated with some aspect of the reproductive condition, as well as with the increasing dryness and temperature which may exist at this stage of growth in the field. Grazing to remove elongating flowering culms will stimulate tillering if conditions favorable for growth prevail.

4164. Leiva, M. J., F. Stuart Chapin III, and R. Fernandez Ales. 1997. **Differences in species composition and diversity among Mediterranean grasslands with different history – the case of California and Spain.** Ecography 20(2):97-106.
Abstract: Species composition and diversity were compared among twenty Mediterranean annual grasslands in northern and central California and central and southern Spain, encompassing climatic gradients and local site variation in topography and soils. Geographic proximity was more important than environmental factors such as climate, topography, and parent material in predicting the species composition of these grasslands, with Californian and Spanish grasslands sharing only 9% of the species and geographically separated regions within each country sharing only 20-32% of the species. This importance of geographic separation in predicting species composition suggests a strong role of dispersal limitation in determining current community composition. Mean species diversity was lower in Californian than in Spanish grasslands and was negatively correlated with cover of annual grasses that tended to be greater in California than in Spain. However, there were few differences in species diversity among sites within either country and patterns of species diversity were unrelated to soil fertility or productivity. We suggest that current grazing regimes contribute to the greater abundance of grasses and lower species diversity of Californian than of Spanish grasslands. The apparent importance of dispersal limitation and grazing in explaining differences in species composition and diversity between Californian and Spanish grasslands and within each country suggest that the structure of these grasslands has been and will continue to be sensitive to human influence.

4165. Leonard, Oliver A. 1956. **Effect on blue oak (*Quercus douglasii*) of 2,4-D and 2,4,5-T concentrates applied to cuts in trunks.** J. Range Manage. 9(1):15-19.
Abstract: The effects of cut-surface applications of the herbicide 2,4-D and 2,4,5-T concentrates on blue oak were studied in relation to spacing, height, and depth of cuts, form and dilution of herbicide, and seasonal differences in sensitivity. Four-inch spacing of the cuts gave the best kills with the least volume of chemical. Cuts made close to the ground were slightly more effective than cuts made

higher on the trunk in killing the tops, but were much more effective in preventing sprouting from the base; however, the sprouts eventually died, so the formation of sprouts was of no importance. Amines of 2,4-D and 2,4,5-T were much more effective when applied to the sapwood than when than when they were applied to the bark. Amines were considerably more effective than esters, especially at the lower dosages used. The 2,4,5-T amine was equal to the amine of 2,4-D while the amine of MCP (triethanolamine) was much less effective. The ester of 2,4,5-T was superior to the ester of 2,4-D. Dilution of 2,4-D amine with water gave no advantage in effectiveness. It increased the time necessary for making effective application and added to the bulk of material to be carried out. An abrupt increase in effectiveness took place between October 6 and November 4. The increase in effectiveness in November appears to have been associated with an increase in soil moisture and a decrease in air temperature. The trees remained sensitive throughout the winter and spring months.

4166. Leonard, Oliver A. 1957. **Delayed kill of live oak brought about by 2,4,5-T applied to cuts.** Pp. 43-44 *in:* Research Progress Reports, Western Weed Control Conf., Western Society of Weed Science.
Abstract: In February 1952, interior live oak (*Quercus wislizenii*) was treated with two formulations of 2,4,5-T amine. The formulations contained 3 lbs of acid equivalent per gallon and the concentrates were applied to hatchet cuts (1 for each 6 inches of circumference). One ml was applied to each cut. About 35 trees and clusters of trees (resulting from resprouting following a past fire event) were treated. There was no difference noted between the two formulations. Plant kill after 2 years was 19%; after 3 years, 23%, and after 5 years, 70%. Top kill was 77% after both 2 and 3 years, and 85% after 5 years. The interesting aspect here was the great increase in plant kill that took place between 3 and 5 years after treatment. This took place because live sprouts that developed around the base of many of the top-killed trees died between the third and fifth year. Although appreciable delayed sprout kill is common with the cut-surface method, this result represents the greatest amount of delayed kill that the author has observed. The reasons for the delayed kill are not understood.

4167. Leonard, Oliver A. 1957. **Effect of monuron on live oak sprouts.** P. 43 *in:* Research Progress Reports, Western Weed Control Conf., Western Society of Weed Science.
Abstract: The herbicide monuron, 3-(*p*-chlorophyenyl)-1,1-dimethulurea, was used to treat areas containing sprouts of interior live oak (*Quercus wislizenii*) trees following their being cleared from rangeland by bulldozer. Treatments were conducted at Hopland in January 1953, as well as at other locations in December 1952. Monuron was applied at the rates of 1, 5, and 25 grams (80% formulation) per group of sprouts. Applications were made to 1, 5, and 25 square feet in order to study the interrelationship between dosage and area treated on kill. Results were recorded in October 1956. In the Hopland trials, at no time were any of the trees more than very slightly affected by the treatment. At other sites, it was noted that monuron was more effective when concentrated at the bases of the oak sprouts. Spreading the same quantity of chemical over 25 times the area had little effect on the sprouts, although enough residual herbicide still remained 4 years later to influence growth of grass. Most oak sprouts were very slow in dying, with most of the kill taking place 3 and 4 years after treatment.

4168. Leonard, Oliver A. 1957. **Effect of phenoxy herbicide concentrates applied to cuts of sprouting tree species.** Weeds 5(4):291-303.
Abstract: The effect of 2,4-D, 2,4,5-T, 2-(2,4-DP), and 2-(2,4,5-TP) concentrations applied to cuts in stems of interior live oak, black oak, and madrone are reported in the present study. The relationship of spacing of the cuts, dosage, seasonal changes in sensitivity, and other factors were studied. Most dependable kills were obtained when all the bark was severed around the trunks. However, good kills could be obtained during the late fall and winter with the cuts spaced every 6 inches around the tree (a cut for each 6 inches of circumference). Best kills appear to be obtained when the chemicals are placed in the sapwood and when the cuts are made near the base of the trees. The latter item appears to be especially important for interior live oak and of lesser importance for black oak and madrone. Amine formulations were somewhat superior to ester formulations; however, the advantage of the amines could be overcome by increasing the dosage with the esters. Although 2,4-D appeared to be generally the most satisfactory of the phenoxy herbicides studied, good results were obtained with 2,4,5-T and 2-(2,4,5-TP) amines. The amines of 2-(2,4-DP) and MCPA were less effective. Monuron and ATA appeared to be without any effect when applied to cuts in live oak. A considerable delay in sprout kill was evident in some cases. Considering all treatments, over one-half of the trees with dead tops that had basal sprouts, eventually died. The delay in death of the sprouts sometimes took from 3 to 5 years and was probably due to the free 2,4-D and 2,4,5-T present in the wood being drawn into the shoots by transpiratory pull. The trees appear most sensitive during the late fall and winter to the cut surface method, and least sensitive during the summer. By increasing the dosage and applying the chemical to continuous cuts, the method can be reasonably effective at all seasons.

4169. Leonard, Oliver A., and Alfred H. Murphy. 1964. **Control of stump sprouts.** Pp. 42 *in:* Research Progress Reports, Western Weed Control Conf., Salt Lake City, UT, Mar. 25-26.
Abstract: About 1,500 blue oak (*Quercus douglasii*) and California black oak (*Q. kelloggii*) stumps were treated from December 14, 1960 through February 14, 1961 on the Hopland Field Station. The treatments involved applications of either alkanolamine salts of 2,4-D or triethylamine salt of 2,4,5-T to the cut surface, using about 1 gm ae per square decimeter of cut surface. One-half of the stumps were cut to a height of 30 cm while the other half were cut about 90 cm high. One half of the stumps were treated immediately after being cut and the other half were treated 7 days after cutting. Some stumps were covered with aluminum foil to protect from rain. Data on sprouting was recorded in 1961, 1962, and 1963. Results on sprouting in 1962 indicated that all variations in the treatments markedly influenced sprouting of both oak species. Sprouting was greatest with 2,4-D amine, for stumps cut high (90 cm), for treatments that were delayed for 7 days, and for stumps that were covered. Results in 1963 indicated that the responses observed in 1962 had become nullified, since most of the sprouts that were alive in 1962 had died with all treatments. Tracer studies with 2,4-D on interior live oak (*Quercus wislizenii*) have indicated that protecting a stump from rain by covering the cut-surface markedly impedes the downward movement of the label, but does not prevent it from occurring. Some movement downward does take place slowly; such movement was observed to occur over a 103-day period during the winter. It appears that in the course of 2 years or more that sufficient movement may take place to be herbicidal to sprouts. It is possible that the total movement is less with covered stumps and that the final kill would be related to dosage; however this aspect has not been studied.

4170. Leonard, Oliver A., and Alfred H. Murphy. 1964. **Stump sprout control.** Calif. Agric. 18(4):7.
Abstract: The cut stumps of blue oak (*Quercus douglasii*) and black oak (*Q. kelloggii*) were treated with 2,4-D or 2,4,5-T to determine the effect of these herbicides for inhibiting sprouting. Also evaluated was height of cut, delay time in treating cuts, and protecting cut surface from weather factors. Although all treatments were eventually successful in sprout control, there was a clear advantage to cutting stumps low and treating with herbicide immediately after

cutting.

4171. Leonard, Oliver A., R. K. Glenn, and D. E. Bayer. 1965. **Studies on the cut-surface method. I. Translocation in blue oak and madrone.** Weeds 13(4):346-351.
Abstract: Translocation of labeled 2,4-dichlorophenoxyacetic acid (2,4-D) and 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) in blue oak (*Quercus douglasii*) seedlings occurred following application of these herbicides to cuts made through the bark into the wood of stems. Downward transport was limited. ^{14}C-labeled 3-amino-1,2,4-triazole (amitrole), maleic hydrazide (MH), urea, and ^{32}P-labeled phosphate translocated extensively into the roots, but had marked effect on translocation of 2,4-D and 2,4,5-T, MH, and urea. The addition of herbicidal amounts of unlabeled 2,4-D and 2,4,5-T reduced translocation of labeled compounds into the roots. Unlabeled 4-amino-3,5,6-trichloropicolinic acid (picloram) or 2,4-D applied to cuts prevented translocation into the roots of all but traces of MH applied to the same cuts. Treatment of blue oak or madrone (*Arbutus menziesii*) trees in the field (15-20 cm diameter) with herbicidal doses of 2,4-D or picloram largely inhibited the downward movement of $^{32}PO_4$ applied to the same cuts at all stages of growth; such interference was less pronounced in madrone than in blue oak. We still face the problem of finding an effective herbicide for woody plants that does not hinder its own pathways for movement, or of discovering how to use currently available herbicides so that their translocation is not hindered.

4172. Leonard, Oliver A., C. E. Carlson, and D. E. Bayer. 1965. **Studies on the cut-surface method. II. Control of blue oak and madrone.** Weeds 13(4):352-356.
Abstract: The control of blue oak (*Quercus douglasii*) was investigated by cut surface applications of water-soluble amine formulations of 2,4-D; ester formulations of 2,4,5-T and silvex; potassium salt of picloram; and ammonium sulfamate. All phenoxy herbicides were relatively effective in controlling blue oak; the least favorable results were obtained with undiluted ester forms of 2,4,5-T and silvex, and ammonia sulfamate. Picloram was more effective than the water soluble amine salts of 2,4-D on both blue oak and madrone (*Arbutus menziesii*). Relatively favorable results were obtained on madrone by single point applications to stems with picloram. Applications to holes one inch deep were more effective than when applied in deeper or shallower holes. Diluting alkanolamine salts of 2,4-D with water and butoxyethanol ester of 2,4,5-T with diesel oil had a generally depressing effect on kill (except for the first dilution of the ester). Plant kill decreased as the diameters of the trees increased. Rainwater analyses did not furnish an explanation for the marked increase in growth of the grass beneath the treated trees.

4173. Leonard, Oliver A., and W. A. Harvey. 1965. **Chemical control of woody plants.** Agric. Exper. Sta. Bull. 812, Div. Agric. Sci., Univ. Calif. 26 pp.
Abstract: Nearly one-half of California's land is covered with woody plants, and about one-third of this cover is brush and non-commercial forest now of little economic value. Some of this land is suitable for conversion for range and crop purposes, other areas may be cleared for watersheds, and still others will eventually be partially cleared for rural living and recreation. California also has extensive commercial coniferous forests whose productivity cannot be maintained without effective measures for reforesting burned-over areas and increasing the productivity of the rest. Herbicides properly used can perform a valuable function in controlling unwanted woody plants while leaving those that are desirable. California can be made a better place to live by landscape improvement and by minimizing the destructiveness of chaparral and forest fires. Herbicides are important in timber production as losses from fire can be reduced by construction of effective fuel breaks made by the chemical removal of underbrush and unwanted trees along ridgetops. This bulletin lists the important herbicides used for controlling woody plants. Tables detailing their preparation and use are presented. Application equipment and methods of application for various chemicals and purposes are detailed. Problems involved in control are discussed and various solutions are given. The bulletin also includes tables showing the reactions of a list of woody plants to various herbicides and treatments.


A. H. Murphy

Researchers examine brush control plots, James III Pasture, Summer 1963

4174. Leonard, Oliver A., and Alfred H. Murphy. 1965. **Relationship between herbicide movement and stump sprouting.** Weeds 13(1):26-30.
Abstract: It was shown that less sprouting of blue oak (*Quercus douglasii*) and California black oak (*Quercus kelloggii*) occurred when treated stumps were: a) cut 30 cm rather than 90 cm high; b) treated at once after cutting rather than after 7 days; c) treated with 2,4,5-T amine rather than with 2,4-D amine; and d) left uncovered rather than covered. The differences between treatments eventually disappeared because of the death of sprouts, possibly due to the levels of herbicide used in making the treatments. The downward movement of carboxyl ^{14}C-labeled 2,4-D and 2,4,5-T, 3-amino-1,2,4-triazole-5-^{14}C, and ^{14}C-labeled urea in interior live oak *(Q. wislizenii*) stumps was studied in El Dorado County. Rainfall, level of 2,4-D applied, and time interval all appeared to influence downward movement.

4175. Leonard, Oliver A., and R. K. Glenn. 1971. **Chamise and interior oak control with *m*-(3,3-dimethylureido) phenyl *tert*-butylcarbamate.** Pp. 28-29 *in:* Research Progress Rep., Western Society of Weed Science, Denver, CO.
Abstract: We studied the control of chamise, *Adenostoma fasciculatum*, and interior live oak, *Quercus wislizenii*, following soil application of NIA 11092 at 4, 8, and 16 lb/a during the winter season. The 4% or 10% granules were applied to soil which was less than one foot deep, mainly clay and underlain by shale. It is estimated that 5 to 15 inches of rain fell during the winter and spring following the applications. Plant kills were estimated in August or September, 1970, which was 1½ to 2½ years following application. Interior live oak was treated on January 9, 1968 at the Fiddletown location in the Sierra. Plant kills were about 90% with the 16 lb/a treatment, but was slight with 4 and 8 lb/a. On a similar soil situation near Hopland similar results were obtained, except that kill with 16 lb/a was about 85%; the applications were made on December 27,

1967. Fenuron pellets (25%) applied at the same rates at the same time killed none of the live oak in these tests.

4176. Lewis, David J. 2001. **Understanding and monitoring California hardwood rangeland watersheds.** Oaks 'n' Folks 17(1):5-6.
Abstract: Watershed functions include the collection, storage, and transport of water. In California's hardwood rangeland watershed, these functions have distinct characteristics resulting from the prevailing Mediterranean climate and vegetation. A team of UC research and extension professionals is involved in conducting long-term watershed scale studies on water yield and water quality, with research sites at both the Hopland and Sierra Foothill R & E Centers. This article describes the need for and the objectives of these field studies, including such topics as the necessity of baseline data collection and calibration, stream flow generation, nitrate concentrations and leaching, and seasonal variability of nutrient transport.

4177. Lewis, David J., Kenneth W. Tate, John M. Harper, and Julie Price. 2001. **Survey identifies sediment sources in North Coast rangelands.** Calif. Agric. 55(4):32-38.
Abstract: We conducted a sediment source survey to gain insight into soil erosion on Northern California rangeland watersheds and to provide information to facilitate informed land-use management, conservation prioritization, and water-quality regulation decisions. The results indicate that by focusing on erosion associated with natural and historical influences, inventory and assessment efforts on these watersheds can characterize the majority of sediment deliverable to streams. While this volume of sediment does not require mitigation under current water-quality regulations, it nonetheless prohibits the ability of in-stream sediment monitoring to detect water-quality changes. Water-quality regulations require managers to create inventories for all sources with 10 cubic yards or more of potentially deliverable sediment. If a monitoring threshold of 100 cubic yards was used, more than 99% of the deliverable sediment identified in this survey would be inventoried. This would require developing inventories for only 82 of the 117 sites in this study. Overall, we determined that rangeland managers can achieve the greatest reductions in sediment generation by focusing on erosion from roads.


A. H. Murphy
UC Davis soils specialist William Wildman samples soils on erosion slip during Soils-Veg School, Lambing Pasture, May 1971

4178. Longhurst, William M. 1957. **A history of squirrel burrow gully formation in relation to grazing.** J. Range Manage. 10(4): 182-184.
Abstract: A historical comparison (1940 and 1955) is made of the progress of gully formation and development initiated by Douglas ground squirrel burrows at sites in Napa County, California. This process results from water flowing through and enlarging rodent burrows which are dug downslope. Once the roof of the burrow collapses, a gully begins to form. The rate of its development may be influenced by the intensity of livestock grazing.

4179. Love, R. Merton, and Alfred H. Murphy. 1955. **Fertilized pastures.** Calif. Agric. 9(7):3.
Abstract: Shortage and abundance of forage at various seasons of the year are typical of much of the rangeland in northern California. From December until the warm weather of spring is one of the periods of feed shortage. On a sheep operation this is usually a critical period because most flocks are lambing and best lamb production can be realized only when both ewes and lambs have plenty of nutritious green feed available. A study was conducted at the Hopland Field Station to evaluate whether N and P fertilizer applied in the fall on seeded pastures might be useful in increasing winter feed. Forage yield tests began the second growing season after planting. During the period from January to March untreated control pastures averaged 335 pounds of dry matter production per acre. The highest N and P rates yielded 4,000 pounds over the same period. Animal gains are still being evaluated.

4180. Love, R. Merton, and William A. Williams. 1956. **Range land development by manipulation of the soil-plant-animal complex in the difficult environments of a Mediterranean-type climate.** Pp. 3-11 *in:* Proc. VII Int. Grassland Congr., Palmerston North, New Zealand.
Abstract: Opportunities now available for grassland manipulation make it possible to assess improved range practices in terms of existing production rather than on the basis of climax vegetation. Manipulation of soil fertility by proper applications of needed nutrients increases forage production, lengthens the grazing period, and improves the nutrition content of the feed. The introduction of better adapted species improves forage production and quality and frequently permits economical utilization of higher levels of soil productivity made possible by fertilization. The compounding of compatible seed mixtures makes possible the establishment of more desirable perennial forage species. Improved forage conditions favorably influence livestock production, but livestock activities also affect forage development. Hence, management of time and intensity of grazing is an important aspect of the complex. Rotational grazing systems have been devised which maximize immediate livestock gains and yet favor maintenance of stands of desirable forage species. There are ways of changing environmental conditions in order to remove the restrictions imposed by soil and climate on existing grassland vegetation. We present illustrations of research demonstrating the feasibility of profitable manipulation of the factors of the soil-plant-animal complex.

4181. Lusk, W. C., Milton B. Jones, Donald T. Torell, and C. M. McKell. 1961. **Medusahead palatability.** J. Range Manage. 14(5):248-251.
Abstract: Numerous reports have indicated that the weedy annual grass, medusahead (*Elymus caput-medusae*), is unpalatable and has lowered rangeland carrying capacity wherever it has invaded. A grazing test was conducted with sheep to investigate the palatability of medusahead on fertilized and unfertilized annual range. The results indicated that: 1) sheep, given a free choice, did eat medusahead as long as it was green; 2) sheep held in a small plot area ate some medusahead even when it had headed out and dried; 3) heavy grazing in the spring resulted in a thinned stand of medusahead

at maturity as compared to a dense stand of medusahead resulting from light or no grazing; 4) fertilized medusahead was grazed more than unfertilized medusahead since a greater amount of medusahead was taken from fertilized plots early in the season. This resulted in less medusahead on the grazed-fertilized area late in the season as compared to grazed-unfertilized areas.

4182. Mackenzie, Andrea, and Adina M. Merenlender. 2000. **Sonoma County Acquisition Plan 2000: a tool for conserving oak woodlands.** Oaks 'n' Folks 16(2):1, 7.
Abstract: A county-wide resource assessment and conservation plan, "Acquisition Plan 2000," for Sonoma County, CA is described. The county's Agricultural Preservation and Open Space District is described. This article describes the cooperative research agreement between UC's IHRMP and the District in developing GIS-based data on natural resources, centering on open space resources. This plan includes a consistent and scientific rationale for prioritizing certain areas of the county for conservation, and criteria for evaluating the conservation potential of individual properties. The plan identifies critical habitats, including oak woodlands, and seeks to acquire conservation easements or to purchase land outright, so as to preserve the areas of highest natural resource values. Impacts of the plan, upon adoption, on the county's oak woodland conservation efforts are described.

4183. Maddox, D. M. 1981. **Introduction, phenology and density of yellow starthistle in coastal, intercoastal and Central Valley situations in California.** Agricultural Research Results ARR-W-20, USDA Agric. Research Service, Western Region, Oakland, CA. 33 pp.
Abstract: Yellow starthistle, *Centaurea solstitialis*, is believed to have originated in Eurasia. More than 1.9 million acres are infested in California where it colonizes rapidly on disturbed soils. It is allelopathic and forms dense stands. When ingested by horses, yellow starthistle causes "chewing disease." Its chronology of introduction in California has been associated with the brick flora in the Mexican or postmission period after 1824. Its field phenology consists of 9 primary growth stages (= phenophases) and 17 substages. A description and key are provided. Yellow starthistle populations were studied in three California areas because they provided different climatic conditions of temperature and precipitation. The locations and habitats selected were Hopland (coastal), Concord (intercoastal), and Woodland (valley). The coastal population had a greater average population density, average plant height, and earlier phenology than did the intercoastal and valley populations. Differences in average precipitation and temperature, seed production, and ratio of kinds of seeds produced were noted at the compared sites. Evidence suggests that California plants are represented by different allopatric populations responding by genotypic differentiation to environmental differences in their habitats. This study is the necessary basis for the biological control investigations of this weed.

4184. Major, Jack, C. M. McKell, and L. J. Berry. 1960. **Improvement of medusahead-infested rangeland.** Leaflet 123, Calif. Agric. Exper. Sta. and Extens. Service. 6 pp.
Abstract: Medusahead (*Elymus caput-medusae*), an annual weedy grass, is invading California's rangelands at a serious rate. Grazing capacity on some ranches has been reduced as much as 75%. Small spot infestations must be controlled even at a high cost, to ensure against spread of the weed to uninfested areas. Chemicals applied at the proper time and rate are effective in controlling medusahead. Reseeding spot infestations is a necessary follow-up treatment. On widespread, long-established stands, chemical control is not economically feasible. Under such conditions, the more productive locations should be chosen for improvement by burning and cultivation, combined with the seeding of legumes fertilized with phosphorus or sulfur, or the seeding of aggressive, locally adapted perennial grasses. Seeding operations should be followed by proper livestock management. On lands where reseeding is inappropriate, a systematic program of reburning may be followed. This pamphlet provides specific recommendations on control of medusahead, some of which are based on research and observations conducted at Hopland.

4185. McCorkle Jr., C. O., Alfred H. Murphy, Lynn Rader, and D. D. Caton. 1964. **Cost of tree removal through chemicals.** J. Range Manage. 17(5):242-244.
Abstract: This paper reports on the costs of chemical tree removal based on data collected at the Hopland Field Station. The diameter, species, treatment time, and moving time between trees were recorded from each of four 1-acre plots. Regression analyses of these data provided estimates of the influence on times of treatment and moving between trees of tree species, diameter, and stand density. Density of tree cover, a major determinant of forage production in woodland-grass ranges, can be changed by chemical treatment of individual trees. Labor and materials costs, the essential cost components, are determined by the quantity of labor and materials used and their prices. Labor and material requirements are functionally related to diameter of trees treated, density of stand, and species treated. Therefore, costs per acre to treat trees can be related to these same variables and, additionally, to the prevailing wage rates and cost of chemical material used.

4186. McCreary, Douglas D. 1989. **Regenerating native oaks in California.** Calif. Agric. 43(1):4-6.
Abstract: Livestock are frequently blamed for poor regeneration of native oaks in California, but research indicates that other factors are also involved. Conditions favoring natural regeneration may occur only once or twice in a century. Artificial regeneration is a practical but currently costly alternative. This research demonstrated that, with proper treatment and planting of acorns and seedlings, California blue and valley oaks can be successfully propagated. If blue oaks are to be seeded directly, acorns should be collected during September of early October while they are still on the trees. After collection, they should be refrigerated immediately (in 1.75-mil zip-lock storage bags) to prevent drying and kept cold until they are planted. Both blue and valley oak acorns can be planted from early fall (after the first soaking rains) until mid-winter. Early sowing is favored. In dry years, early initial growth may give seedlings a better chance to become established before soil moisture becomes limiting. These results have important implications for the production of native oaks in bare-root nurseries. Early-season sowing should allow nursery operators to produce larger seedlings in a shorter time. Blue oak seedlings can be successfully established by directly planting small container plants. Excellent survival and vigorous growth can be achieved if seedlings are planted in deep augured holes and irrigated and fertilized during the first summer after planting, and if the area around them is kept free of competing vegetation. Damage to seedlings from insects, mice, and deer can be prevented by caging with aluminum window screen. Additional measures to protect seedlings from livestock may be necessary in grazed areas. Research on the artificial regeneration of oaks is continuing. Investigations include seedling container size, fertilization, effects of acorn size, direct-seeding acorns versus planting seedlings, and irrigation practices.

4187. McCreary, Doug. 2001. **Agroforestry is promising for previously cleared hardwood rangelands.** Calif. Agric. 55(6): 37-41.
Abstract: Livestock grazing is the primary economic use of most hardwood rangelands in the coastal foothills of California. But owners of these lands may be able to increase revenues by simultaneously producing two crops, trees and sheep. In 1993, we

initiated an agroforestry project at the Hopland Research and Extension Center to study the ability of three pine species and one hybrid to grow on cleared hardwood rangelands that are grazed by sheep. This study also evaluated the response of planted seedlings to auger and fertilization treatments. After 8 years, tree survival has been high, growth has been vigorous and damage from sheep minimal. Monterey pine and KMX pine, a cross between Monterey and knobcone pine, had the most growth. Incidence of western gall rust, *Endocronartium harknessii*, was low (approx. 3% of trees exhibited galls), but it was more common on Monterey pine than on KMX pine. Because of concern that pitch canker, a disease of Monterey pine caused by the fungus *Fusarium subglutinans*, planting of Monterey pine outside its natural range could post a risk of expanding the range of this disease and perhaps spreading it to douglas fir or other tree species. These results suggest that some pine species are promising for planting on grazing lands in coastal foothills where oaks and other hardwoods have been removed.

4188. McDougald, Neil K., W. James Clawson, James W. Bartolome, and William E. Frost. 1991. **Estimating livestock grazing capacity on California annual rangeland.** Range Sci. Rep. 29, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 2 pp.
Abstract: Efficient grazing use of annual rangeland requires a quick, efficient, accurate and repeatable procedure to set initial livestock stocking levels. Scorecards developed contain grazing capacities based on: 1) the productivity of a site, expressed as the relationship between forage production and canopy cover; 2) grazing use, expressed as the relationship between slope and grazing pressure; and 3) a level of residual dry matter or litter, which indicates allowable grazing pressure and utilization. These variables are displayed as a field scorecard which the experienced range manager can use to estimate grazing capacity on annual rangeland along with actual livestock grazing use history.

4189. McHenry, W. B., and Alfred H. Murphy. 1985. **Weed management of California rangeland.** Pp. 413-423 *in:* Principles of Weed Control in California. Thomson Publications, Fresno, CA.
Abstract: California rangeland is a discontinuous and exceedingly diverse agricultural sector of the state occupying approximately 36-46 million acres (36-46% of the total surface area). Historical changes in the state's rangeland vegetation and reviewed, and the current status of rangeland vegetation is described. The principal type of livestock using these rangelands are cattle and sheep, and range provides 60% of the total feed requirement for these meat animals. In addition to the resident forage species, a number of improved forage grasses and legumes have been introduced to lengthen the productive grazing season and to increase the nutritional quality of rangelands. Optimum establishment and utilization of this feed is enhanced by managing herbaceous and woody (brush and/or trees) competition. Management strategies typically focus on prescribed burning, but also include follow-up measures such as grazing management, additional use of fire, mechanical weed control, and herbicides. Biological strategies of weed control employing insects and pathogens have been used on a limited scale, but will hopefully play a larger role in the future. If all these techniques are judiciously applied in accordance with local needs, the management of range vegetation could result in at least a 3- to 4-fold increase in value.

4190. McKell, Cyrus M., Alma M. Wilson, and Milton B. Jones. 1961. **A flotation method for easy separation of roots from soil samples.** Agron. J. 53:56-57.
Abstract: A method for separating plant roots from soil, important for the study of plant growth, is described. A shortcoming of most previous methods is their failure to separate roots from soil particles too large to pass through a screen. The method described is based on the principle of soil-elution. Improvements on previous methods include use of a pressure stream of water to wash and circulate the soil-root-water mixture, the use of relatively small volumes of water, and an assembly-line arrangement of root washing units. This method is accurate for obtaining root samples inasmuch as all roots are washed free of soil and are retained on a fine mesh screen. It also has the advantage of separating the large soil particles and gravel from the roots by leaving them on the bottom of the container.

4191. McKell, Cyrus M., Milton B. Jones, and Eugene R. Perrier. 1962. **Root production and accumulation of root material on fertilized annual range.** Agron. J. 54:459-462.
Abstract: Annual rangeland plots treated for 4 consecutive years with 66.6 lbs/ac P, 100 lbs/ac N, 100 lbs/ac N plus 66.6 lbs/ac P, or with no fertilizer were studied to determine the amount of root material (macro-organic matter) produced and accumulated in response to the various fertilizer treatments. Root material was obtained from the top 24 inches of soil by using a hand-driven 2.37-inch-diameter core sampler. The total amount of root material produced was greatest on the plots receiving N. Production of root materials on plots fertilized with P and on plots fertilized with a combination of P and N appeared to be greater than on nonfertilized plots. The amount of root material decreased with increasing depth, and no accumulation of roots was found at any particular depth in response to fertilizer treatment.

4192. Menke, John W. 1989. **Management controls on productivity.** Pp. 173-199 *in:* L. F. Huenneke and H. Mooney (eds.), Grassland Structure and Function: California Annual Grassland. Kluwer Academic Publ., Dordrecht, The Netherlands.
Abstract: Replacement of the native perennial flora of California grasslands by alien annual plants has had a major impact on management options available to stewards of the grassland. The tenacity of highly competitive annual species has made it difficult to control productivity for the purpose of improving performance of domestic livestock. On the other hand, the resilience of the annual vegetation forgives abusive practices time and time again. Availability of small-seeded annual legumes from other Mediterranean-climate regions of the world has provided a technology that alleviates one of the primary factors limiting productivity, nitrogen. This technology is well developed and available to the rancher. Poor returns from ranching in general, due to national agricultural policies, seem to be the only obstacle to greater adoption of annual legume pasture improvement programs. Eight number of vegetation management technologies have been used to increase grassland productivity. Prescribed fire is used to reduce litter accumulation of undesirable weed species and to remove competing shrubs and trees of low forage value. Annual legumes and perennial grasses are seeded to increase availability of high quality forages. Fertilizers are used alone or as part of a legume-based pasture improvement program. Irrigation has been used to lengthen the growing season of annual species. Some annual grasslands subject to soil compaction problems and also suitable for farming are used in a dual fashion for dryland grain farming and livestock grazing on a rotational basis. Until recently, herbicides were used in an array of different ways to make other improvements possible. Lack of response of the annual plants to season and intensity of grazing has resulted in little application of grazing systems, but new systems are now being investigated. Need for fire control, wildlife habitat improvement, and increased watershed production can fit into range improvement programs for multiple use benefits. Serious questions remain about the sustainability and cumulative effects of our grassland management activities. Clearly the demand for cordwood can and does exceed the supply, given the large and rapidly growing population of California. Grassland weed problems and lack of regeneration of deciduous savanna and woodland communities are problems needing greater attention. Educators and extension persons alike must take the long view in teaching the public about the long-term value of its natural resources.

4193. Menke, John W. 1992. **Grazing and fire management for native perennial grass restoration in California grasslands.** Fremontia 20(2):22-25.
Abstract: There is increasing interest in reestablishing native perennial grasses on California grassland sites which are presently dominated by introduced, alien annual grasses and forbs. Perennial grasses lengthen the grazing season, have greater capacity to stabilize surface and sub-soils, are less flammable, and increase grassland soil fertility and organic matter thereby sustaining productivity. Studies have been conducted on fire and grazing management on grasslands at the Hopland Field Station and elsewhere. Results suggest that two grazing schemes are useful as restoration tools: 1) short duration, high intensity sheep or cattle grazing for several days in early spring to remove alien weed seed and open sward canopy; and 2) summer or dormant season high intensity livestock grazing to remove litter or "thatch" accumulation. Burning has proven useful in late spring by decreasing alien annual plant seed production and removing litter. Summer burning on sites where above ground biomass <2,500 kg/ha serves both to reduce the density of annual plants with flammable seeds, and stimulate fragmentation of perennial bunchgrass into vigorous "daughter" plants. On productive sites (>2,500 kg/ha) summer fire intensity can kill mature perennial grasses, making prior grazing or mowing necessary. Once native perennials reach desired stand densities, more frequent grazing and combined burning every third or fourth year are beneficial in maintaining that population.

4194. Menke, John W., and G. Eric Bradford. 1992. **Rangelands.** Agric., Ecosystems, and Environ. 42:141-163.
Abstract: Effective integration of the three main goals of rangeland management– economic gain through livestock production, management of game animals for recreational use, and conservation of biological diversity– is essential and will form a cornerstone of conservation of biological diversity for future generations. Rangelands encompass nearly 50% of the earth's land area and is defined as land where people have intervened to manage the vegetation with livestock for economic gain. The introduction of domestic animals to a natural plant community has profound effects on the composition of the vegetation, soil erosion by wind and water, and on the population density and species composition of native organisms. Rangelands vary in their biological and economic productivity throughout the world and the greatest impacts on biodiversity usually occurs on sites with the highest productivity. Worldwide overgrazing is the primary issue in range management. The basic tenet of range science is that the reduction of number of livestock animals will lead to greater productivity per unit area. Management of western rangelands is discussed from a historical standpoint. Various factors affecting rangelands are discussed, including perturbations by traditional grazing practices, problems with animal management, introduced domestic animals and feral animals, livestock predators, and management of native animals for meat production. A classification of rangelands into four categories is presented with opportunities for proper management to enhance biological diversity and range productivity discussed for each type. Ways to manage rangelands for biodiversity include fire and utilization of restoration techniques.

4195. Merenlender, Adina M., and Colin N. Brooks. 1997. **Integrating geographic information at state, regional and local scales: an essential step for watershed management, restoration, and monitoring.** Pp. 159-164 *in:* Proc. Sixth Biennial Watershed Management Conference (S. Sommarstrom, ed.), Lake Tahoe, CA. Report No. 92, Centers for Water and Wildland Resources, Water Resources Center, Univ. Calif. Davis.
Abstract: Advancements in computer technologies have dramatically increased our ability to integrate and analyze geographic information, making a geographic information system (GIS) the standard tool for natural resource management, ecological monitoring, and land-use policy making. Despite the fact that these statewide efforts are increasingly focusing on information collected at the scale of watersheds, little opportunity exists to incorporate data from local projects into regional and state data repository efforts. This omission limits our ability to extrapolate information gained at the local level to other large-scale watershed projects. An example of a GIS for Parsons Creek, a Russian River tributary, demonstrates the limitations of using large scale digital data collected from available federal and state sources for local project planning. A better integration of local, regional, and statewide GIS efforts is needed to improve our ability to restore and monitor watershed function, a necessary step to revive California's declining fisheries.

4196. Merenlender, Adina M., and Colin N. Brooks. 1997. **Integrating information at state, regional and local scales: an essential step for watershed management, restoration and monitoring.** Oaks 'n' Folks 12(2):4, 7.
Abstract: The utility of geographic information systems (GIS), a computer mapping and analysis tool, is described for studying watersheds in order to integrate physical and biological data at various scales. A case study of Parsons Creek in Mendocino County, a tributary to the Russian River, is described. The limitations of satellite imagery, large scale aerial photos, and other data currently available are discussed; site truthing is essential to obtain accurate data. The needs for establishment of standards for future digital data and for extensive documentation of meta-data are described. Accurate data can assist in watershed planning, project implementation, and monitoring.


Robert M. Timm

Bob Keiffer (second from left) coordinates planting of riparian vegetation along Parsons Creek, aided by Calif. Conservation Corps personnel, Spring 1993

4197. Murphy, Alfred H., and R. Merton Love. 1950. **Hairy oatgrass, *Danthonia pilosa*, as a weedy range grass.** Calif. State Dept. of Agric. Bull. 39(3):118-124.
Abstract: The occurrence of hairy oatgrass (*Danthonia pilosa*), a low-growing perennial bunchgrass of poor forage value in coastal sections of northwestern California, has resulted in its being considered as a weedy grass under certain range conditions. It has demonstrated an ability to become established on lands capable of producing good forage. When it becomes established on natural pastures, it crowds out better forage plants and at the same time extends its stand. The University of California initiated studies to determine the most feasible methods of control. A number of different chemicals were used to determine whether a satisfactory control could be obtained. Unfortunately, the amount of chemicals needed to provide satisfactory control was in excess of an economical

amount. It was therefore concluded that chemical control would not be satisfactory on large scale infestations. There was some evidence that fertilization and/or seeding competitive plants might reduce the vigor of *D. pilosa* to a considerable degree. Fertilizer trials on existing *D. pilosa* stands demonstrated that a change in soil fertility by itself on a well-established stand of the grass did not result in significant changes in the stand composition within a reasonable time or at an economical fertilizer rate. Experiments combining fertilization with seeded legumes showed more promise. A two-year study, still in progress, indicates that the best control is possible by the use of competitive plants, especially seeded legume species such as subclover and birdsfoot trefoil, combined with fertilizer. Using these methods several large acreages have been planted and will be closely studied to determine if *D. pilosa* will reinfest these areas to any serious degree.

4198. Murphy, Alfred H., R. Merton Love, and Lester J. Berry. 1954. **Improving Klamath weed ranges.** Circular 437, Calif. Agric. Exper. Stn. and Extens. Service. 15 pp.
Abstract: Klamath weed (*Hypericum perforatum*) has been a major range pest on much of the grazing land of northern California, and it has also infested abandoned cropland. The weed is most prevalent in the north coastal and north central valley zones. The weed causes blistering and a sensitivity of the skin which results in an inferior range animal. More important, the weed competes with the good forage species of the areas, and the reduction of feed results in a poorer quality of livestock. Acreage of infested land in selected California counties is given. This publication outlines and describes methods and strategies for Klamath weed control, including biological control by leaf-eating beetles (*Chrysolina gemellata*), chemical control with 2,4-D, grazing management, and cultivation and seeding.

4199. Murphy, Alfred H. 1955. **Range cover after Klamath weed.** Calif. Agric. 9(5):4, 13-14.
Abstract: Two test ranches in southeastern Humboldt County were selected to study the vegetational changes and the plants most likely to replace Klamath weed (*Hypericum perforatum*) while biological control by *Chrysolina* beetles was in progress. Prior to biological control, Klamath weed composed 30 to 70% of the vegetation, which had the effect of crowding out good forage species and thus subjecting livestock to malnutrition and disease because of poor range conditions. Sheep were used to graze all study pastures. While southeastern Humboldt County is capable of supporting a stand predominated by perennial grasses, past stocking practices reduced the grass composition to primarily annuals. During the study, perennial grasses were encouraged by withholding grazing during the period of seedhead development until seed shattered, and by rotating grazing to develop thrifty grass plants. After 4 years of controlled animal use, a greater change in perennial grasses was not possible because of low initial population densities. The invasion of other weedy range plants on those areas formerly occupied by Klamath weed was an important factor, as Klamath weed cover ranged from only a trace to just 15% after 4 years of biological control. On these Klamath weed ranges, medusahead (*Elymus caput-medusae*) thrived and provided serious competition to the more desirable forage plants. Range improvements can be achieved only where better annuals and perennials replace the undesirable plants.

4200. Murphy, Alfred H. 1955. **Vegetational changes during biological control of Klamath weed.** J. Range Manage. 8(2):76-79.
Abstract: Changes in vegetational composition were studied on two Humboldt County range areas from 1948 to 1953 during biological control of Klamath weed (*Hypericum perforatum*). Set grazing periods in spring and summer were run in conjunction with the study until 1951. In all cases where beetles were noted to be feeding during the late spring and summer, Klamath weed was reduced to a minor part of the forage or completely eliminated the subsequent year. Both the annual grasses and forbs were aggressive competitors for the vacated space. In one case annual grasses were most aggressive, but in two other cases forbs and annual grasses were equally aggressive. Out of three trial areas, the perennial grasses increased in percentage density in only one area. Weedy grasses, such as medusahead (*Elymus caput-medusae*), showed some increase.

4201. Murphy, Alfred H., R. Merton Love, Milton B. Jones, and Donald T. Torell. 1961. **Measurement of forage and sheep production on native range and pastures fertilized with nitrogen and phosphorus.** Calif. Agric. 15(6):2-4.
Abstract: A 3-year study compared forage and sheep production on native annual range and pastures fertilized with nitrogen and phosphorus. The primary benefit of fertilization was to increase the availability of early feed. This coincided with lambing so that from about November 15 until March 1 the increased supply of high quality feed was available for lambs and ewes. The native pastures, in contrast, were low in feed production at this time. The gain of lambs after March 1 was lower on the fertilized pastures as compared to the native pastures, however. The fertilized pastures had a high percentage of weedy and undesirable plant species which mature early and become relatively unpalatable earlier than do the native pastures. The lambs in the fertilized pastures thus had less palatable feed to select from late in the growing season. These differences were also reflected in forage quality. Protein percentage was 4.4% higher in January on fertilized pastures than native range, and only 1.7% higher at the conclusion of grazing in early June. The value received in meat, wool, and grazing use indicated that the cost of fertilizer was returned plus a profit of $13.04 per acre.


A. H. Murphy

HFS crew conducts rangeland burn for medusahead control, Upper Horse Pasture, May 1951

4202. Murphy, Alfred H., and W. C. Lusk. 1961. **Timing medusahead burns to destroy more seed – save good grasses.** Calif. Agric. 15(11):6-7.
Abstract: One method of controlling medusahead (*Elymus caput-medusae)* is to burn the grass when dry to destroy the seed crop. In a comparative study, it was determined that burning when soft chess had scattered its seed and medusahead seed was intact would favor soft chess total seed numbers. Germination test on seeds indicates medusahead seed develops about 20 days later than soft chess.

4203. Murphy, Alfred H. 1962. **Response of hardinggrass to grazing and cutting.** Calif. Agric. 16(10):10.
Abstract: Hardinggrass (*Phalaris tuberosa*) is widely recommended in California for range and dryland pasture use, yet many of the factors that contribute to keeping this plant in a thrifty condition are

not known. Research is underway at the Hopland Field Station to determine the effects on grazing and cutting this grass at various stages of its growing cycle. In initial studies, plants are being grazed and cut at frequent intervals. A sheep is confined to a small plot and held on this area until grass is later as close to the ground level as possible to simulate the cutting treatment. The first series of clipping and grazing tests was started in early spring and continued at regular intervals until seed-head maturity. The plants' behavior will be related to the time of herbage removal, chemical composition, and environmental conditions.

4204. Murphy, Alfred H., Burgess L. Kay, and Cyrus M. McKell. 1962. **EPTC pre-emergence herbicide aids establishment of clovers in dryland pastures.** Calif. Agric. 16(7):10-12.
Abstract: EPTC (ethyl N, N-di-n-propylthiolcarbamate) can aid in the establishment of seeded annual clovers in dryland pastures where a weedy annual grass problem exists. Trials conducted in Mendocino, Mariposa, San Benito, and Santa Barbara counties indicated that pre-emergence herbicide will reduce competition from annual grasses but not from forbs such as mustard and filaree. Success is still dependent upon climate, fertilizer treatment, grazing use, and other related factors. EPTC application provides a method of altering species composition of a pasture. It can be applied in the late summer to prevent seed germination, in contrast to many herbicides that must be applied to living plants.

4205. Murphy, Alfred H., Burgess L. Kay, and Cyrus M. McKell. 1963. **Clover aid: EPTC cuts grass competition.** Agrichem West 6(9):31-33.
Abstract: Annual clovers are adaptable over a wide area of California and provide a high protein forage crop as well as improving soil fertility with their nitrogen fixing ability. Difficulty in establishing clover is encountered when the resident cover of grasses and broadleaf weeds is abundant and vigorous. The pre-emergent herbicide EPTC, reportedly selective for annual grass seed, was tested for its ability to decrease weeds on dryland pastures in Mariposa, San Benito, Santa Barbara, and Mendocino counties. The trials indicated that EPTC will reduce the competition from annual grasses but not from forbs such as mustard and filaree. EPTC application provides a method of altering species composition of a pasture and can be applied in the late summer to prevent weed seed germination in contrast to many herbicides which must be applied to living plants. This study showed that it is effective without soil incorporation when applied to dry ranges, thus it might be used to control weedy range grasses, such as medusahead, in certain situations.

4206. Murphy, Alfred H., and Beecher Crampton. 1964. **Quality and yield of forage as affected by chemical removal of blue oak (*Quercus douglasii*).** J. Range Manage. 17(3):142-144.
Abstract: Treatment of blue oak by the cut-surface or basal frill method with 2,4-D results in some changes of species composition and considerable difference in yield. Forage yield was very sensitive to the tree treatment, with production exceeding that of open ground during the growing seasons following the chemical treatment. Four annual grasses exhibited the greatest change in species composition under tree treatment with soft chess and wild oats increasing and ripgut and mouse barley decreasing. In the forbs, shade-loving species were eliminated, but others showed no consistent change due to tree treatment.

4207. Murphy, Alfred H. 1967. **Controlled burning in chamise chaparral.** Pp. 245-255 *in:* Proc. Calif. Tall Timbers Fire Ecology Conf., Hoberg, CA, Nov. 9-10.
Abstract: Chamise brush lands may be managed for livestock, wildlife, water, or reduced fire hazard. Regardless of the goal, brush control is an essential part of management. This paper describes procedures for burning and follow-up treatment, including herbicide treatment and grazing, to control brush regrowth and establish herbaceous cover. Application of these procedures to livestock, wildlife, watershed, and fire protection management is discussed. An active program of brushland management is essential for the future development of California's rural lands.

4208. Murphy, Alfred H. 1970. **Predicted forage yield based on fall precipitation in California annual grasslands.** J. Range Manage. 23(5):363-365.
Abstract: The initiation of fall forage growth in the California annual grasslands is dependent upon the first half-inch of effective rainfall. Annual yield of this forage is influenced by the amount of precipitation received by the third week in November. At that time a determination can be made as to whether expected annual production will be low, medium, or high. A coefficient of correlation value (r = .70), significant at the 1% level, was obtained between yield and total rainfall through November 20.

4209. Murphy, Alfred H., Milton B. Jones, and R. Merton Love. 1970. **Effect of clipping interval on botanical composition of subterranean clover and its associated plants.** J. Range Manage. 23(3):196-199.
Abstract: The use of subterranean clover (*Trifolium subterraneum*) as a livestock feed for range pastures in California is receiving widespread acceptance; best use interval information is needed. Clipping intervals of 1, 2, 4, and 6 weeks, and no clipping were compared to determine the effect of clipping interval on botanical composition. No consistent difference in the botanical composition of subclover resulted from clipping interval after the first two years. The unclipped treatment was mostly grass while the composition of subclover diminished each year until none was present in the sixth year. Clipping reduced the percentage of grass and the interval did not make consistent difference. Composition of forbs in the unclipped treatment was markedly increased by clipping; however, the interval produced no consistent difference. Yields taken in the sixth clipping year showed only minor difference due to clipping interval.


Robert M. Timm

Superintendent Al Murphy leads UC Davis field class on visit to chaparral site, February 1978

4210. Murphy, Alfred H., and Donald T. Torell. 1972. **Brushland range improvement... economic values.** Calif. Agric. 26(6):3-6.
Abstract: Brushland conversion to allow improved livestock forage was studied at Hopland on the 865-acre James pasture, which was subdivided into three fenced pastures. This article describes the conversion of brushland to improved pasture in James III, a 387-acre pasture at elevations ranging between 1,600 and 2,700 feet. Treatments utilizing crushing, controlled burning, herbicide application, seeding of grasses and legumes, fertilizing, and grazing

management all were employed, and costs were documented. Grasses that established most successfully were hardinggrass and Palestine strain of orchardgrass. Blando brome established well initially but was not as persistent a feed producer for long-range purposes. Three legumes, rose clover, subclover, and lana vetch, were seeded but generally were successful only in areas below 2,000 ft elevation, and damage was severe from birds and rodents, thus reducing initial stands. The greatest impact to increased grazing yield was the replacement of worthless brush areas by seeding useful grasses and legumes. Improved areas provided livestock feed in excess of 2,000 lbs/ac, dry weight basis. By the 8th year following initiation of treatments, net returns from livestock utilization exceeded improvement costs on an annual basis. From the 8th year onward, with minimal maintenance or improvement costs needed to maintain the pastures in an improved condition, net returns may be expected to increase at a substantial rate.

4211. Murphy, Alfred H., and Lester J. Berry. 1973. **Range pasture benefits through tree removal.** Calif. Agric. 27(1):8-10.
***Abstract*:** At Hopland during an 11-year study of a watershed (Watershed II) involving vegetative conversion from predominantly woody plants to herbaceous forage, the total increase in ranch income through livestock use was $133.60 per acre. This value takes into account $57.09 per acre production value without improvement and treatment costs of $34.87. Treatment included chemical control of trees and other woody plants, followed by burning of the area and seeding to grasses and legumes. Thus, by reducing the woody plant component of the watershed and replacing it with herbage livestock could use, the product values were increased fourfold. It should be noted that no fertilizer was applied in this improvement study – and that its use would probably have given a greater magnitude of production increase. It is also expected that this higher level of production can be sustained with a minimum of maintenance costs.

4212. Murphy, Alfred H., Milton B. Jones, W. James Clawson, and J. E. Street. 1973. **Management of clovers on California annual grasslands.** Circular 564, Calif. Agric. Exper. Stn. and Exten. Serv., Univ. Calif. 20 pp.
Abstract: The nonirrigated grasslands of California are dominated by annual herbaceous species growing on soils of generally low fertility. These soils are usually deficient in nitrogen and often in phosphorus and sulfur. To increase production on these grasslands, nitrogen must be added either by fertilization or by growing clovers which, together with root-nodule bacteria, have the ability to convert the nitrogen in the soil air into a form that can be used by plants. This circular discusses the advantages of seeding clovers on grasslands, describes several species, recommends management practices, and suggests suitable mixtures for California's various rainfall and planting zones.

Controlled burn of Watershed I, September 5, 1956

4213. Murphy, Alfred H., and Oliver A. Leonard. 1974. **Chaparral shrub control as influenced by grazing, herbicides, and fire.** Calif. Agric. 28(1):10-13.
Abstract: Best control of chaparral shrubs on rangeland at the Hopland Field Station has been achieved with the use of herbicides. In both grazed and ungrazed areas, 3 treatments using chemical control (standard brush killer, 2,4-D and 2,4,5-T) reduced the brush to less than 1% of the plant cover within 4 years and maintained a very low level for the 14-year period of the experiment. Grazing without other control had little influence on the results, except for a re-occurrence of poison oak in the ungrazed areas. Fire reduced the amount of brush for the first two years, but its effectiveness peaked out in the sixth year with a gradual decline thereafter.

4214. Murphy, Alfred H., and R. Merton Love. 1974. **Maximizing production from dryland seeded pastures.** Pp. 779-784 *in:* Proc. XII Int. Grassland Congr., Moscow, U.S.S.R.
Abstract: Selected areas on most pasture livestock operations can produce high yields if correct management techniques are applied. Since the investment in seed and fertilizer is returned in increased animal grazing values within 2 to 3 years, the quick return reduces investment risk to the livestock grower. Factors responsible for good results include application of needed fertilizer materials, grasses and legumes adapted to the location, restricting access to wildlife grazers, and selecting good soil sites. Applying these principles, requirement per sheep is reduced from 0.8 ha to only 0.1 ha per year.

A. H. Murphy

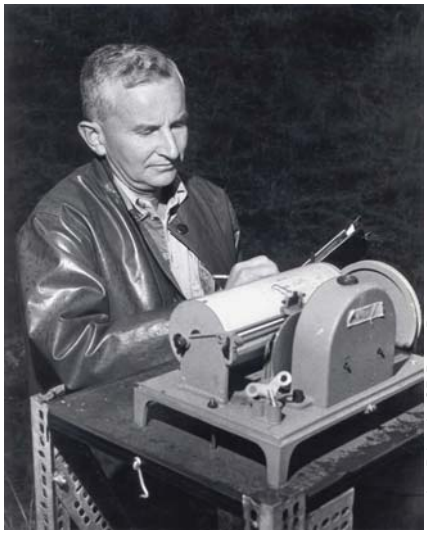
Seeding former chaparral area in James III pasture with range drill, October 1963

4215. Murphy, Alfred H., Oliver A. Leonard, and Donald T. Torell. 1975. **Chaparral shrub control as influenced by grazing, herbicides, and fire.** Down to Earth 31(3):1-8.
Abstract: Best control of chaparral shrubs on rangeland at Hopland Field Station has been achieved with the use of herbicides 2,4-D and 2,4,5-T. In both grazed and ungrazed areas, these chemical were applied for 3 years and reduced the brush to less than 1% of the plant cover within four years. The brush was maintained at a very low level for the 14-year period of the experiment without subsequent chemical application. Grazing without other controls had little influence on the results, except for a reoccurrence of poison oak in ungrazed areas. When fire is used in conjunction with grazing, its effectiveness is greatly improved; in this study about 60% less brush grew when the burned area was grazed. Fire reduced the composition of brush for the first two years, but peaked out in the sixth year with a gradual decline thereafter. If the burned area is not grazed, repeated controlled burns are needed about every 3 to 4 years to control brush, but less frequently if the area is heavily used by livestock. The costs and returns of converting chaparral brushlands to good grazing lands were evaluated on a 865-acre study area divided into three fenced treatment areas (James I, II, and III).

Treatments were applied over a 5-year period. By the eighth year following initiation of treatments, net returns from livestock utilization exceeded improvement costs on an annual basis. From the eighth year onward, with minimal maintenance or improvement costs needed to maintain the pastures in an improved condition, net returns may be expected to increase at a substantial rate.

4216. Murphy, Alfred H. 1976. **Clovers for improving annual grasslands (Abstract).** P. 53 *in:* Abstracts, 29th Ann. Mtng., Soc. Range Manage., Omaha, NE, Feb. 16-20.
Abstract: Many of the grasslands in California are deficient in nitrogen; one area of research to improve these rangelands has been the development of a suitable type of legume plant to correct this deficiency. During the past decade, two legumes, rose and subterranean clovers, have shown promise of filling this need. In addition to the role of enriching the soil nitrogen, these legume species greatly improve the quality and quantity of forage available to livestock. These grasslands are not devoid of legumes, as numerous species exist; but their propagation is formidable. For example, a resident legume, bur clover, is relatively abundant in some locations, but seed production is difficult, limiting available supplies. It is also characterized by high hard seed content, resulting in spotty planting success. However, reliable seed supplies of rose and subterranean clovers are available from Australia, and to a limited degree in the United States. Because these clovers have been widely tested as adaptable in California, they are the species offering the best opportunity for use on annual grasslands. In clover seeding tests, problems of stand establishment were evident; an evaluation program for solving the problems has been in progress for many varied annual grassland types. Developing use for these clovers was accomplished by solving problems in three categories, the first being to find additional varieties of these clovers. In the early 1940s when testing of these legumes was initiated, only one variety of rose clover and 3 varieties of subterranean clover were available; now the total is over 15 varieties, which translates into a maturity range of 6 to 8 weeks. Now on California grassland, where rainfall varies from 10 to 60 inches annually, clovers with maturity dates matching the rainfall pattern can be selected. Secondly, fertilizer studies indicated that for most range soils, phosphorus and/or sulfur were essential for clover establishment. It has also been shown that a program of fertilizer applications over the years was necessary to maintain these clovers in a vigorous condition. A third factor in the clover culture was effective nodulation. Many clover failures could be traced to use of the wrong inoculant and incorrect application to the seed. Pellet inoculation developed in Australia and New Zealand provided a means of adequately attaching and protecting the bacteria on the seed. Private companies within the seed industry did much to select viable strains of inoculant that would develop compatible nodules on legume roots, and range researchers with the University of California tested inoculants on many varied grassland sites. This three-phased program of investigation of a range need has provided answers whereby the land manager can now use these clovers with reliable results, thus improving not only his feed resources but the soil nitrogen content in a much less costly manner than if applied as chemical fertilizer.

4217. Murphy, Alfred H. 1976. **Watershed management increases rangeland productivity.** Calif. Agric. 30(7):16-21.
Abstract: Soon after establishment of the Hopland Field Station, two watershed areas were selected for intensive management studies. Hydrologists at UC Davis initiated the studies with the cooperation of researchers in agricultural economics, agronomy, animal science, botany, forestry, and wildlife. The two selected sites were typical of many rangeland areas of northern California, having a mixture of grasses, trees, and shrubs on relatively steep ground. They had been used by wildlife and livestock for many years. The studies were concerned with disposition of water from the time it falls as precipitation, until it leaves the area as runoff or through evaporation. Included were the effects of vegetation on interception of rainfall, use of moisture, and ability to hold or retard erosion; the method by which moisture enters the soil profile for storage and later release; manipulation of vegetation to provide good feed for animals without making exorbitant demands on water supplies; animal utilization that is compatible with other uses of a watershed; and the economics of management methods associated with watershed management. Vegetative conversions from woody plants to grasses and forbs are described, along with resulting results of the management treatments implemented. While forage production increased dramatically, runoff also significantly increased, and soil erosion was a serious problem at some locations.


Joe Price Jr., SR Press Democrat

Al Murphy transcribes data on stream flow, Watershed II, October 1964

4218. Murphy, Alfred H., Harold F. Heady, and John W. Menke. 1976. **Vegetation changes produce benefits.** Calif. Agric. 30(7): 22-24.
Abstract: The Hopland range area has more than 500 plant species. The vegetation can be divided into herbaceous and woody plants, both of which can be manipulated in a variety of ways to enhance feed production. The herbaceous vegetation can be managed by mowing for hay or grazing; applying fertilizer to encourage growth; introducing exotic herbaceous species such as subterranean clover to improve forage production and quality; and using chemicals and fire to alter growth patterns. The woody vegetation, trees and shrubs, can be managed in much the same way. Trees generally grow on deeper soils and favor a more moist, northern exposure. Dense tree canopies nearly eliminate herbaceous ground cover. To increase feed production, these woody plants can be removed or thinned. Opening canopy can increase feed production 4- to 5-fold. Brush-covered areas offer a greater management challenge because more plant species are involved, the soils are less productive, and the terrain rough and steep. Brushlands can be managed, however, with the judicious use of grazing, fire, and/or chemicals. Proper brush management can lead to complete conversion to herbaceous cover or any degree of brush density required for land-use needs. It is necessary to determine whether the economics of production can sustain the costs of range manipulations. Generally, more productive soils result in quicker returns. This means that site selection is an important consideration if range management is to be profitable.

4219. Murphy, Alfred H. 1978. **Benefits of chaparral improvement to livestock and wildlife.** Pp. 84-91 *in:* Proc. Calif.

Weed Control Conf., Vol. 30, Monterey, CA, Jan. 16-18.
Abstract: Brush management in California is important for a number of reasons: 1) fire damage costs in excess of one million dollars per year, this could be much reduced by judicious use of fire, chemicals and grazing; 2) water is the life blood of California's economy, annual runoff from shrub covered slopes can be increased as much as 90% by removing the water using shrubs; 3) wildlife populations thrive better on shrubs managed as a supply - as an example, open brush will support 40 to 110 deer per square mile whereas in dense brush, deer population is down to 10 to 30 head per square mile; and 4) livestock production on shrub areas can increase meat production by the ratio of 4:1 over untreated areas. These examples of potential improvements that may be achieved on areas occupied by shrubs point out the importance of this problem for California rangelands. A vegetative conversion from brushland to annual grasses and forbs is described. Brush control methods included crushing with a bulldozer, burning, herbicide applications, and grazing. Seeding of hardinggrass, Palestine orchard grass, smilo, Blando brome, crimson clover, rose clover, and subterranean clover, accompanied by fertilization to aid establishment. It was concluded that chemical treatment (herbicide applications) were by far the most efficient method of brush control, and that grazing when used in the absence of other brush control methods had little influence on the results. Results of the use of fire were greatly enhanced by subsequent grazing.

4220. Murphy, Alfred H. 1980. **Oak trees and livestock – management options.** Pp. 329-332 *in:* Proc. Symp. Ecol., Manage. and Utilization of Calif. Oaks, Claremont, CA, Jan. 26-28, 1979. USDA For. Serv., Gen. Tech. Rep. PSW-44.
Abstract: In California, approximately 10 million acres of woodland grass type offer opportunities for modification of the tree cover to improve their use in livestock management. Research projects on oak grasslands at the Hopland Field Station, over the past decade, have provided information for the improvement of quality and quantity of range forage on mixed oak-grass vegetation, impacts of tree removal on water productivity, and the expectation of soil movement on various geologic formations by the removal of tree cover. The removal of oak tree cover will modify the rangeland ecology. In many situations, forage quality and quantity will improve, springs and stream flow will increase, and an economic return can be obtained if the tree material is harvested for firewood. If a large percentage of the trees are killed, under some geologic conditions, erosion will increase in terms of channel scouring as well as by land slips. The browse value of oaks within reach of grazing animals will be lost and the fall acorn crops will be reduced. It is important that rangeland operators fully assess the changes that will result from tree removal to determine whether they will benefit future land use plans.


Guy E. Connolly
Field day demonstrating vegetation conversion and management, James III Pasture, May 1974

4221. Murphy, Alfred H. 1986. **Strategic use of legumes to improve annual grassland.** P. 302 *in:* P. J. Joss, P. W. Lynch, and O. B. Williams (eds.), Rangelands: A Resource Under Siege. Proc. 2nd Int. Rangeland Congress, May 13-18, 1985, Adelaide, Australia. Cambridge Univ. Press, Cambridge.
Abstract: Annual grasslands can achieve their best potential production by the introduction of selected annual legumes. Such success requires the strategic use of legume varieties, fertilizers, proper seed inoculation, correct seeding time, and proper grazing use. This report summarizes the process of rangeland improvement conducted on the Hopland Field Station's annual grasslands, among other locations, including techniques to establish and manage subterranean clover (*Trifolium subterraneum*) and other legumes as part of the grassland flora.

4222. Murphy, Alfred H., Milton B. Jones, and R. Merton Love. 1986. **Comparison of animal yields on annual grasslands-stocking rates and improvement practices.** Range Sci. Rep. 6, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 9 pp.
Abstract: Most dryland annual range pastures are producing livestock products much below their potential. Production and quality of range forage can be increased by seeding clovers and fertilizing with phosphorus and sulfur (P and S). To demonstrate how such improvements may be implemented, an area of 285 acres at the Hopland Field Station was divided into four pastures where sheep grazing could be controlled and seeding with fertilization would be feasible. Pastures were standardized for grazing forage potential as they would be grazed at equal rates. Two pastures were seeded with subclover and then fertilized with P and S every second year. Response to the improvement practice was measured by animal unit months (AUM) and pounds gain of sheep per acre before and after treatment, over a 24-year period (1959-1982). The seeded-fertilized pastures resulted in a gain of 53 pounds of sheep per acre due to treatment, while the pastures without improvement resulted in a loss of 10 pounds per acre. The improvements resulted in an increase of 1.08 AUM per acre for sheep while the unimproved pastures increased 0.05 AUM per acre. It can be concluded that pastures of the type studied have the potential for considerable increase in grazing capacity and yield of meat with the judicious seeding of subclover and use of P and S fertilizers.

4223. Olson, Kent D., Theodore E. Adams, and Alfred H. Murphy. 1983. **Evaluating the profitability of brush management and oak tree thinning for range improvement.** Calif. Agric. 37(9-10):6, 7, 22.
Abstract: Clearing rangeland of dense brush thickets or stands of oak trees produces obvious benefits on the better soils; more and better feed for domestic and wild animals; improved water yield in the watershed; and reduced fire hazard. But there are also costs, which need to be weighed against potential returns before the decision is made to improve the land. Weather and market conditions cause both physical production and product price to vary, but the costs of improvement vary little, especially after they are incurred. This study estimates the annual costs of two range improvement practices, brush management and oak tree thinning, and discusses the comparison of these costs with potential returns when the returns are not known with certainty. Data from vegetation conversion work done in James III pasture, including detailed tabulation of labor, machinery and equipment, and materials costs, are re-evaluated using 1982 prices. An equivalent annuity approach is applied to the data to derive an economic analysis; this approach is recommended where the yields and prices are not known and estimates of benefits are very uncertain.

4224. Olson, Kent D., Mel R. George, John W. Menke, Alfred H. Murphy, Jeff Van Horne, and Lu Lohr. 1987. **Incorporating weather variation into California rangeland stocking rate decisions.** Staff Papers Series P87-40, Dept. of Agric. & Appl.

Econ., Univ. Minnesota, St. Paul, MN. 26 pp.
Abstract: The "conventional wisdom" in managing California's rangeland is to stock at 80% of the average forage production. The stocking rate decision was evaluated with iterative solutions of a linear programming model for a ranch based in the western foothills of the Northern Sierra Nevada, and is based in part on data from the UC Sierra Foothill Field Station. A herd size of 135 cows and 1,030 stockers was chosen based on average forage production. To reflect conservative management, the stocker herd was decreased to 927, 824, and 721 stockers (90%, 80%, and 70% of 1,030 stockers). The relationship between weather variability and forage production was estimated on the basis of historical data and subjective field experience. The LP model was solved for these variations with the stocking rate fixed at the above rates. Since the stocking rate for average forage production has a higher expected return than these conservative stocking rates, the "conventional wisdom" is not risk neutral, but risk-averse to some degree. To evaluate the impact of income variance, the choice of herd size was analyzed by the mean-variance tradeoff, stochastic dominance analysis, and utility estimation. Both the mean-variance tradeoff and second-degree stochastic dominance eliminated the highest stocking rate, but did not provide enough information to rank the other stocking rates. Using a quadratic function to estimate utility showed that ranchers who were averse to risk would stock at rates lower than the conventional wisdom. The conventional wisdom of stocking at 80% of the average range forage production was shown to be close to risk neutrality.

4225. Olson, Kent D., Mel R. George, and Alfred H. Murphy. 1989. **Estimating weather and forage relationships.** Range Sci. Rep. 22, Dept. of Agron. & Range Sci., Univ. Calif. Davis. 15 pp.
Abstract: The relationships between weather and forage production are discussed and analyzed in this paper. Previous studies found a relationship between total forage production and weather during the season. This paper analyzes statistical relationships between weather and forage at three range research stations in California: Hopland Field Station, Sierra Foothill Field Station, and San Joaquin Experimental Range. In the first section, a statistically significant relationship between mid-season forage production and weather conditions at HFS was not found. In the second section, seasonal weather data were used to estimate the predictability of winter and spring weather condition based on fall weather conditions. With a few exceptions, fall weather data had no significant predictive value. In the third section, the ability to predict seasonal forage production from weather information is developed based on subjective knowledge. Such information is particularly useful to new managers, and it can be used in making stocking rate decisions.


Robert J. Keiffer

Center ag technicians Dana Edson and Steve Fernandes install fence to protect Parsons Creek riparian zone, October 1992

4226. Opperman, Jeff. 1998. **Deer herbivory and riparian restoration.** Oaks 'n' Folks 13(1):4.
Abstract: Three riparian corridors in Mendocino County were studied to evaluate the influence of deer herbivory on rates of natural revegetation. Areas with deer exclosures were compared to unfenced control reaches. Study sites were on Robinson Creek, Feliz Creek, and Parsons Creek, all of which are tributaries to the Russian River. Differences between vegetation inside and outside exclosure were dramatic. Regeneration included several willow species, cottonwood, alder, and Oregon ash. Mean regeneration within exclosures was 45 trees per 10 square meters, compared with 4 trees per 10 square meters in control sites. These results suggest that deer may play a large role in reducing the rate of natural regeneration of degraded riparian corridors. Eliminating deer herbivory through exclosure appears to be the key factor in recovery of riparian corridors evaluated; recovery occurred without planting, irrigation, or channel modification. While deer herbivory may not be as significant at other locations or along other types of streams, it may be possible to identify other stressors that act as ecological constraints to riparian vegetative recovery.

4227. Passof, Peter C. 1987. **Developing an educational program to address the management of California's hardwood rangeland.** Pp. 394-399 *in:* Symposium on Multiple-Use Manage. of California's Hardwood Resources, San Luis Obispo, CA, Nov. 12-14, 1986. USDA For. Serv., Pac. Southwest For. & Range Expt. Sta., Gen. Tech. Rep. PSW-100.
Abstract: This paper traces the development of the University of California's efforts to produce educational programs addressing the management of oak grass woodland over the past 35 years. It includes mention of the founding of the Hopland Field Station in 1951, as well as subsequent research and extension activities at this facility. The paper mainly focuses on current efforts under the new Integrated Hardwood Range Management Program including the UC Hardwood Range Manual, "Preliminary Guidelines for Managing California's Hardwood Rangelands." A four-point educational strategy with several program goals is offered as part of future University planning.

4228. Peters, Amy. 1994. **Biology and control of barb goatgrass (*Aegilops triuncialis*).** M.S. Thesis, Oregon State Univ. 79 pp.
Abstract: This research examined the biology of barb goatgrass (*Aegilops triuncialis*), a weedy annual grass that is invading the rangelands of California. Germination and root growth characteristics of barb goatgrass were compared to soft chess (*Bromus mollis*), medusahead rye (*Taeniatherum caput-medusae*), slender wild oats (*Avena barbata*), and subterranean clover (*Trifolium subterraneum*) to determine what advantages barb goatgrass might have when establishing in a plant community. Barb goatgrass germinated under a wide range of temperatures, between 5 and 25°C. This was a wider temperature range than associated species. Root growth rates under greenhouse conditions that simulate spring conditions on California grasslands were greatest for barb goatgrass and slender wild oats. Rooting area observed in glass sided boxes was greatest for goatgrass. Barb goatgrass populations increased with sheep grazing. Increasing grazing pressure resulted in increasing goatgrass density. Barb goatgrass invades both grazed and ungrazed pastures, however higher density of this noxious weed was found in grazed pastures. Barb goatgrass can be controlled with 1.12 kg ai/ha glyphosate (Roundup), but desirable species will likely need to be reseeded to occupy the site.

4229. Peters, Amy, D. E. Johnson, and Mel R. George. 1996. **Barb goatgrass: a threat to California rangelands.** Rangelands 18(1):8-10.
Abstract: Barb goatgrass (*Aegilops triuncialis*), a noxious weed from Eurasia, is invading California's rangelands. This weed has

negligible forage value and can reduce livestock forage production from 50 to more than 75%. It crowds out desirable forage species and causes mechanical injury to domestic livestock because of its sharp spikelets and barbed awns. Its rapid growth, low palatability, and deeply penetrating roots make it a dominant competitor in many California plant communities. Range expansion of this invasive weed in California is graphically illustrated with maps of distribution comparing its locations in 1973 and in 1995. Grazing, burning, and herbicide treatments, either alone or in combination, are potential control methods; while mowing alone can encourage its spread in some situations, mowing can be useful when combined with other control treatments. Glyphosate (RoundUp) applied at 1 lb/acre was found to be an effective control treatment and should be followed by reseeding with a perennial grass / clover mixture.

4230. Phillips, Donald A., and James P. Bennett. 1978. **Measuring symbiotic nitrogen fixation in rangeland plots of *Trifolium subterraneum* and *Bromus mollis*.** Agron. J. 70:671-674.
Abstract: Accurate assessment of seasonal nitrogen fixation in improved rangeland is an important objective for researchers investigating N budgets and management impact. The ^{15}N A-value technique and the acetylene reduction method were compared for their accuracy in determining seasonal symbiotic N_2 fixation on a ground area basis in rangeland plots of *Trifolium subterraneum* and *Bromus mollis*. To simulate range management practices, seeds were planted at 10, 141, or 1970 seeds/m^2 in pure stands or 50:50 mixtures in Laughlin loam. Amounts of N_2, fixed, calculated by the ^{15}N A-value technique, varied significantly with planting density and proportion of clover at different densities. Seasonal, symbiotic N_2 fixation, calculated from the acetylene reduction method, did not vary significantly with either planting density or proportion of clover. It is concluded that with appropriate studies on possible differences in isotope accumulation by a grass and a legume, including morphological, physiological, and biochemical differences, the ^{15}N A-value technique should be more quantitative and discriminatory than the acetylene reduction technique. The single season sampling requirement of the ^{15}N A-value technique also is more amenable to the overall goal of determining the effect of range management systems on symbiotic N_2 fixation.

4231. Phillips, Donald A., Milton B. Jones, and D. Michael Center. 1987. **Intensive management of small rangeland units increases forage and lamb productivity.** Calif. Agric. 41(1-2):4-6.
Abstract: Planting clover seeds inoculated with *Rhizobium* bacteria and fertilizing with adequate phosphorus and sulfur can significantly increase forage production on numerous rangeland soils. The phosphorus and sulfur promote total plant growth, and the clover uses *Rhizobium* to fix nitrogen, a source of low-cost nitrogen fertilizer. Specific recommendations for the species of clover and the amount of phosphorus and sulfur vary with climate and soil type. Information for each locality is available from UC Cooperative Extension Farm Advisors, but general recommendations for annual rangeland would be as follows: 1) Plant a minimum of 10 pounds per acre of subclover (*Trifolium subterraneum*), rose clover (*T. hirtum*), or both in areas that receive more than 10 inches of annual precipitation. Both clovers use a special *Rhizobium* inoculum which is available commercially. 2) Fertilize at planting with 200 pounds per acre of 0-38-0-20, a mixture produced by combining treble superphosphate and elemental sulfur. The same fertilizer treatment normally will be required every other year to provide optimum phosphorus and sulfur, but with proper grazing management, the clover should persist indefinitely, and the *Rhizobium* will keep on fixing nitrogen.

4232. Pitt, Michael D. 1975. **The effects of site, season, weather patterns, grazing and brush conversions on annual vegetation, Watershed II, Hopland Field Station.** Ph.D. Dissertation, Univ. Calif. Berkeley. 281 pp.
Abstract: The influences of site, season, weather patterns, grazing, and brush conversion on standing crop, cover, and botanical composition of the subsequent annual vegetation were investigated from 1955 to 1973 at the Hopland Field Station. Average runoff from Watershed II following brush conversion in 1959 was compared to runoff prior to brush conversion. Brush conversion trebled total standing crop. Much of this increase occurred on sites formerly supporting very dense brush. However, standing crop also increased on sites supporting open grassland. Regressions of standing crop on weather variables clarified important interactions between temperature and moisture patterns throughout the growing season. Annual vegetation on all sites responded similarly to these weather patterns. However, standing crop on the converted sites never attained the productivity of sites which were historically grassland. Botanical composition following brush conversion also differed between sites as grassland and brush converted sites were dominated by shorter and taller annual plants respectively. Sheep grazing utilized approximately 50% of the standing crop and produced only minor changes in botanical composition. Legumes were less abundant in grazed as opposed to ungrazed vegetation, particularly in formerly dense sites where grazing animals may have been attracted by taller vegetation. Runoff increased following conversion of brushy to grassy vegetation. Sedimentation and soil slippage in the vicinity of streams also increased, particularly after the root systems of woody vegetation on the slopes of these streams decayed. Runoff highly correlated with total precipitation. Once annual vegetation became established, standing crop, cover, and botanical composition of the vegetation exerted only negligible influences on total runoff. Regressions of standing crop, clovers, and filaree on weather patterns produced excellent predictive equations useful as guidelines for proper animal stocking rates. These relationships, based upon easily measured weather variables, became particularly useful when implemented in incremental, seasonal stages.

4233. Pitt, Michael D., Robert H. Burgy, and Harold F. Heady. 1978. **Influences of brush conversion and weather patterns on runoff from a northern California watershed.** J. Range Manage. 31(1):23-27.
Abstract: The influences of brush conversion, herbage productivity, and annual weather patterns on runoff emanating from Watershed II, Hopland Field Station, were investigated during the years 1955-1970 inclusive. Grassy vegetation following brush conversion produced approximately 59% more runoff as a percentage of total precipitation than did woody vegetation prior to brush conversion. Once this grassy vegetation became established however, the relative degree of cover and standing crop from one year to the next exerted only negligible influences on total runoff from the watershed. The coefficients associated with cover and standing crop in the simple regression equations for runoff never exceeded 0.44, indicating that a unit increase in either cover or standing crop produces less than a unit increase in runoff. Interestingly, both cover and standing crop positively correlated with runoff, suggesting that increasing cover and standing crop of grassy vegetation produce greater amounts of runoff. However, these relationships among runoff, cover, and standing crop actually represent association with the overwhelming influence of total precipitation, which positively correlated with all three of these variables. Indeed, total precipitation rather than temperature and rainfall patterns was primarily responsible for annual variability in total runoff emanating from Watershed II subsequent to brush conversion. The first four variables entering the step-wise multiple regression equation of runoff through June 1 on weather patterns all describe amounts of rainfall as opposed to temperature patterns. Although periodicity and intensity of storms as well as temperature patterns certainly influence total water released from any watershed, the single variable, total precipitation through June 1, described 92% of the variability in annual runoff from Watershed II.

In addition to increased runoff, brush conversion at this site drastically increased sedimentation and soil slippage in the vicinity of streams, particularly after the root systems of the dense, woody vegetation on these slopes decayed. Leaving some stream bank vegetation intact may have minimized that undesirable result of brush conversion on Watershed II.

4234. Pitt, Michael D., and Harold F. Heady. 1978. **Responses of annual vegetation to temperature and rainfall pattern in northern California.** Ecology 59(2):336-350.
Abstract: Weather patterns significantly influence annual vegetation, both within and between years. The impact of these weather patterns on standing crop, cover, and botanical composition were investigated during the years 1955-1973 inclusive. Standing crop increased as the growing season progressed from March to June while cover declined. *Erodium* spp., *Carduus pycnocephalus*, *Geranium* spp., and *Hypochoreris glabra* all declined between these two months. Other annual species increased in botanical composition as the growing season progressed. Weather patterns primarily influenced total standing crop during the initial period of plant growth. Following germination, temperatures were typically warm and conducive to plant growth; drought at this time suppressed total standing crop. Consistent precipitation following fall germination, and again during the period of rapid plant growth in spring, contributes to a "grass year" in the annual type. The sequence of freezing temperatures in relation to phenology of developing grass seedlings determines the relative proportion of annual grass species from one year to the next. Botanical composition of *Trifolium* spp. and *Medicago hispida* depends upon mild autumn weather, particularly when such fall weather favors none of the annual grass species. Botanical composition of *Erodium* spp. positively correlated with weather patterns associated with dry fall conditions. Multiple regressions of standing crop on weather patterns produced useful guidelines for manipulating animal units to achieve complete utilization of available forage, particularly when these equations were implemented in seasonal stages.


Guy E. Connolly

Range improvement from conversion of chaparral to grassland, Lookout Peak, November 1966

4235. Pitt, Michael D., and Harold F. Heady. 1979. **The effects of grazing intensity on annual vegetation.** J. Range Manage. 32(2): 109-114.
Abstract: Pastures grazed by sheep at moderate and 1½, 2, and 2½ times the moderate stocking rate from 1969 to 1973 were analyzed for relative changes in cover, herbage productivity, and botanical composition. Soft chess and filaree occupy climax and intermediate stages of plant succession, respectively. From 1972-1973 these two plant species displayed opposite trends in botanical composition as a function of earlier grazing intensity. Soft chess increased in response to moderate grazing pressure (pasture S3) but decreased in response to heavy grazing pressure (pasture S2). Conversely, filaree declined under moderate stocking while increasing under heavy stocking rates. These results indicate that extremes of grazing intensity can produce residual impacts on botanical composition of soft chess and filaree for at least 1 year following removal of grazing animals. These residual impacts are consistent with the successional stages of soft chess and filaree and may result from the influence of different levels of mulch on germination and subsequent growth. However, mulch accumulation as a function of grazing intensity does not exert as much influence on botanical composition as do variable weather patterns. From 1970-1972, both filaree and soft chess responded similarly among all four pastures regardless of grazing treatment. Thus, grazing intensity only infrequently exerted a 1-year residual impact on botanical composition. Even this residual impact, because of the more significant influence of annual weather patterns on botanical composition of annual vegetation, would rarely last 2 or 3 years. These same conclusions also apply to cover and herbage productivity, which responded similarly among all four pastures throughout the study period. Although very heavy grazing apparently depressed forage production during the final year of study, absolute productivity differences between moderate and heavy grazing pressures remained managerially insignificant. Moreover, annual variability for both cover and productivity within each stocking rate was more pronounced than the relative differences between stocking rates. Therefore, the residual influences of grazing on cover and total forage production are negligible when compared to these same influences of annual weather patterns. Indeed, following only a single year of rest from grazing animals, both cover and forage production in all four pastures generally responded to annual growing conditions as if no previous grazing treatments existed. Finally, results form this study give further confirmation that the California annual grassland is tolerant to a wider range of stocking rates and degrees of herbage utilization.

4236. Platou, J. S., Roberta Irish, and Milton B. Jones. 1982. **Sulfur – the fourth major nutrient.** The Sulfur Institute, Washington, D.C. 32 pp.
Abstract: Nitrogen (N), phosphorus (P), and potassium (K) have traditionally been known as the major nutrients. Crops need large amounts of these elements and fertilizer programs are designed to supply them in adequate amounts. Another nutrient, sulfur (S), is also needed in large amounts by crops. Many crops contain as much S as P. Sulfur ranks in importance with N and P in the formation of proteins, and it is an integral component of certain vitamins and enzymes. In the past, commonly used fertilizers contained large amounts of S and generally applied enough of this element to meet the needs of crops. However, increasing the use of more concentrated fertilizer materials which contain little or no S has decreased the supply of S to plants. At the same time, higher crop yields have increased the uptake of S from the soil. Soils which originally contained sufficient S often become deficient as agriculture is intensified, unless S-containing fertilizers are used. On S-deficient soils, the quality as well as the yield of crops are reduced unless S is included in the fertilizer treatment. Sulfur fertilizers and sources of sulfur are described in this booklet.

4237. Quinn, L. R. C., G. O. Mott, V. A. Bisschoff, Milton B. Jones, and G. L. Da Rocha. 1965. **Beef production of six tropical grasses in central Brazil.** Pp. 1015-1020 *in:* Proc. IX Int. Grassland Congr., Brazil.
Abstract: Six tropical grasses were studied under grazing with Zebu steers in Central Brazil for a three-year period. The forages were Colonião, Jaragua, Pangola, Molasses grass, Tanganyika and Coastal Bermuda. All pastures received nitrogen and phosphorus during

planting and grass establishment. Then prior to placement of animals in the trial, a split-plot feature was introduced to compare additional phosphorus and a yearly application of nitrogen vs. no further fertilization. The extra fertilizer resulted in higher stocking rates and production of beef per hectare in all pastures except Molasses grass, indicating greater forage yields, but did not increase daily animal gains within any one forage. The data also indicate that: 1) Jaragua and Colonião produced the highest daily gains per steer. 2) Pangola, Colonião and Jaragua were superior to the others in rate of stocking. 3) Pangola, Colonião and Jaragua had the greatest liveweight gains per hectare with near equal beef production. 4) Pangola was the most aggressive forage, outranking the other five grasses in suppression of Common Bahia and other unwanted grass and weed species.

4238. Rendig, Victor V., Milton B. Jones, D. Michael Center, Gerardo S. Besga, and L. Domingo. 1986. **Interactions of sulfur and selenium in forage nutrition and utilization.** 13th Congress of the Int. Soil Science Society, Hamburg, Germany.
Abstract: *Abstract unavailable.*

4239. Rosiere, R. E., and Donald T. Torell. 1982. **Influence of stocking rate on performance of ewes and lambs grazing naturalized and improved California annual range.** Pp. 380-383 *in:* Proc. West. Sect. Am. Soc. Anim. Sci., Vol. 33.
Abstract: A stocking rate trial was conducted in coastal northern California on annual grassland range fertilized and overseeded to subterranean clover and on annual woodland range. Three pastures of each range type were continuously grazed at 100%, 150% and 200% of moderate use for 2 years. Range herbage productivity and utilization were determined while sheep performance parameters and animal turnoff/cash returns were compared among stocking rates and between range types over years. There were no significant differences in lamb crop percentage, weaning weight, ewe fleece weight, and ewe mortality due to stocking rate. Neither was there significant effect on wool per hectare. Improved grassland produced 146 kg more lamb and 18 kg more wool per hectare than woodland range (183 kg lamb; 22 kg wool vs. 37 kg lamb; 4 kg wool for the respective range types). The only important effect of grazing intensity on range species was an increase of subclover at the highest stocking rate. Supplementation of breeding ewes was necessary on unimproved range at the 150% and 200% stocking rates during the fall season to prevent starvation but this did not increase lamb crop over that of unsupplemented ewes on moderately grazed woodland range. Moderate stocking was preferable to heavy grazing on unimproved annual range where most effect was on sheep performance and ranch economy.

4240. Rosiere, R. E., and Charles E. Vaughn. 1986. **Nutrient content of sheep diets on a serpentine barrens range site.** J. Range Manage. 39(1):8-13.
Abstract: Nutritional composition of sheep diets from a serpentine barrens range site was determined at various seasons and stages of plant growth and compared to diets from three other annual range sites. Sheep diets from the serpentine site tended to be more nutritious, ranking in the highest pair of sites in digestibility, digestible energy, crude protein, and ether extract, and containing highest concentrations of magnesium. These differences were subtle and had limited application to management. Nutritional differences attributable to plant phenology were inconsistent but more dramatic than those due to site. Late summer and winter were potentially critical periods for brood ewes with protein and energy, respectively, likely to be marginal or possibly deficient. Contents of nutrients and nutritional properties did not differ between available herbage and forage selected by sheep form serpentine barrens.

4241. Rosiere, R. E. 1987. **An evaluation of grazing intensity influences on California annual range.** J. Range Manage. 40(2):160-165.
Abstract: Influences of grazing intensity on species composition and herbage production of grass-woodland and improved grassland subtypes of annual range were evaluated over a 5-year period in coastal northern California using 3 grazing treatments (100, 150, and 200% of moderate stocking). Herbage utilization did not differ significantly between the 2 subtypes but averaged 42, 52, and 69% for the respective treatments. Plant species and production responses differed significantly between woodland and grassland subtypes. On woodland, ripgut brome (*Bromus rigidus*) and wild oats (*Avena barbata* and *A. fatua*) were most sensitive to grazing intensity while wild barley (*Hordeum leporinum*) and annual fescue (*Festuca dertonensis*) were least sensitive. On improved grassland, subterranean clover (*Trifolium subterraneum*) increased and soft chess (*Bromus mollis*) decreased with increasing grazing intensity. Soft chess remained most plentiful on woodland range under heaviest grazing and it continued to be a major species under heavy grazing of grassland, demonstrating tolerance to grazing intensity. Filaree (*Erodium botrys* and *E. cicutarium*) declined on woodland but increased on grassland as grazing intensified. Peak standing crop was not significantly affected by grazing intensity on woodland range but was greatest at 150% of moderate stocking and lowest at 200% of moderate stocking on grassland range. Decline in grassland herbage yield under heaviest grazing was due to reduction of soft chess which was replaced by subterranean clover. Effects of grazing intensity on range composition and productivity were confounded by innate differences in ranges and yearly weather patterns. Herbage production was impacted more by annual growing conditions than by grazing regimens, but there was no correlation between total annual precipitation and peak standing crop.

4242. Schmidt, Robert H. 1987. **Hardwood regeneration: a new look.** Restor. and Manage. Notes 5(2):89.
Abstract: Recent surveys have indicated that at least 3 species of oaks are regenerating poorly in California. Probable factors influencing regeneration are rodent predation on acorns and seedlings, grazing mammal predation (wild and domestic), competition for nutrients and water with introduced annual grasses, and modified soil dynamics. The University of California's Division of Agriculture and Natural Resources, in cooperation with the California Department of Forestry and Fire Protection, has initiated a 10-year research and education program designed to enhance the long-term stability of these species. Sixteen research projects currently are being funded, and 5 specialists have been hired and located throughout the state to initiate regional research and education programs.

4243. Schmidt, Robert H. (Editor). 1988. **First Progress Report, July 1986 - December 1987.** Integrated Hardwood Range Management Program. Cooperative Extension, Div. Agric. & Nat. Resour., Univ. Calif. Davis. 25 pp.
Abstract: This first progress report describes the development, mission, and activities of the Integrated Hardwood Range Management Program within the Division of Agric. & Natural Resources, Univ. of California. Particular topics addressed include oak regeneration; maintenance of wildlife habitat diversity; consequences of hardwood range conversion; development of alternative management strategies; and monitoring the status, condition, and use of hardwood rangelands. Ongoing research and extension activities are summarized.

4244. Schmidt, Robert H., and Pamela J. Tinnin (Editors). 1989. **Second Progress Report, January 1988 - January 1989.** Integrated Hardwood Range Management Program. Forestry & Resource Mgmt., Univ. Calif. Berkeley. 24 pp.
Abstract: Progress in research and extension within the Integrated Hardwood Range Management Program (IHRMP) is summarized.

Case studies described include Project Acorn, the Agriculture and Natural Resources Youth Workshop at the San Joaquin Experimental Range, a "Construction Among the Oaks" workshop, involvement in hardwood range ordinance development in Monterey County, an Englemann oak geographic information system, and an oak woodland owner survey.

4245. Schmidt, Robert H. 1990. **An oak woodland fairy story.** Calif. Cattleman 73(11):14-15, 65.
Abstract: This story is an entirely fictional narrative describing how a young couple on a small ranch in California's oak woodlands hypothetically might utilize the University of California's Integrated Hardwood Range Management Program (IHRMP). The IHRMP was started to help enhance, manage, and protect California's hardwood resources, most of which are owned and managed by ranchers. The IHRMP recognize that profitable ranchers are the key to maintaining oak woodlands as wildlife habitat, open space, and productive agricultural land. They are less likely to subdivide their ranches and degrade the native wildlife habitat. The University of California, the California Department of Forestry, and the California Department of Fish and Game are teaming up to assist ranchers in increasing their profitability. Ranchers are being taught how to inventory their oak resources and plan for a sustained yield firewood harvesting operation, leasing techniques for establishing a hunt club on both owned and leased property along with methods for improving wildlife habitat, new predation management techniques for reducing livestock losses, and new holistic livestock management strategies for utilizing existing resources most efficiently.

4246. Schmidt, Robert H. 1991. **Defining and refining value for riparian systems.** Rangelands 13(2):80-82.
Abstract: The preservation of riparian systems requires a closer look at the costs and benefits of various management scenarios. The management dilemmas will not be solved with a "stream-huggers vs. cowboys" mentality. All options have not been fully explored, and the result is that our riparian systems are still disappearing faster than we can regenerate or restore them. If all parties take a real-world perspective at the situation, perhaps things can be turned around. Although this paper is not an exhaustive review of all the factors involved in either the conversion or preservation of riparian systems, it does outline some specific areas which require additional attention. Agriculture can benefit with a "we care about riparian habitat" philosophy. Environmentalists can benefit from a "we care about agriculture" philosophy. We have everything to win.

4247. Schmidt, Robert H. 1991. **Despite landowner favor, oak groves likely to diminish in size and number.** Calif. Agric. 45(6):16-18.
***Abstract*:** A survey of landowners in unincorporated parts of Yolo County indicates that they perceive many advantages and few drawbacks to oak-grove ownership. Valley oak acreage is used for farming, wildlife habitat, livestock grazing, houses and outbuildings, and firewood production. However, without new strategies to protect and replace them, existing groves will most likely decrease in size and distribution as properties turn over and new owners and management concerns take over.

4248. Scrivner, Jerry H., D. Michael Center, and Milton B. Jones. 1986. **A rising plate meter for estimating production and utilization.** J. Range Manage. 39(5):475-477.
Abstract: The rising plate meter (RPM) was used to determine forage production and livestock utilization in a rotational grazing system on improved annual pasture in California. Prior to rotating livestock, herbage weight (y) was related to meter reading (x) by the linear model: y = a bx. Forage utilization by sheep was estimated by summing growth and disappearance in grazed pastures. Forage disappearance for pastures was based on meter readings before and after grazing. Plant growth in grazed pastures for the same period was based on meter readings for pastures not then grazed. Use of RPM in a rotational grazing system proved to be a quick and effective way of assessing forage growth and utilization.


A. H. Murphy
Postdoctoral agronomist Jerry Scrivner measures vegetative production, November 1985

4249. Shock, Clinton C., Milton B. Jones, and William A. Williams. 1980. **Fate of fertilizer sulfur on annual range soils (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 175.
Abstract: A lysimeter experiment using radioactively labeled ^{35}S was conducted for 2 years to estimate the effect of sulfur fertilizer on forage yields and the rate of loss of applied sulfate sulfur. Plant responses to sulfur were measured by using pure stands and mixtures of three plant species representative of three forage types typically present in local annual grasslands. Leachate volumes and plant dry weights were measured and both were analyzed for total S and ^{35}S. The effect of sulfur fertilization and species on total sulfur uptake per lysimeter was highly significant in the first year. Subterranean clover and the soft chess - subterranean clover mixture contained more fertilizer S on a ppm basis in the first year and 0.68% in the second year. The species composition in each lysimeter had a marked influence on the volume of leachate in both years and on sulfur loss in the first year. The high loss of sulfate sulfur in the leachate from the lysimeters suggests that other forms of sulfur may be more efficient in increasing the long-range productivity of these soils.

4250. Shock, Clinton C., Milton B. Jones, William A. Williams, and D. Michael Center. 1981. **Competition among annual forage species for sulfur and sulfur cycling as measured in lysimeters (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 265.
Abstract: Competition effects were measured by using pure stands and mixtures of three plant species important in California annual grasslands. The ratios of the dry weights of subclover to soft chess and subclover to filaree increased as the sulfur supply was increased (0, 10, and 80 kg S/ha). The ratio of filaree to soft chess increased with 0-10 kg S/ha but not for 10-80 kg S/ha. Subclover took up more fertilizer sulfate than other competing species at the highest level of sulfur application. Leachate losses of fertilizer sulfate averaged 24% where 80 kg S/ha were applied but were only 2% with 10 kg S/ha. Leachate losses of both fertilizer sulfate and water volume were greatest under pure stands of filaree and least under subclover, and both parameters were intermediate under soft chess and species mixtures.

4251. Shock, Clinton C., William A. Williams, Milton B. Jones, D. Michael Center, and Donald A. Phillips. 1982. **Enhancement of subclover N_2 fixation by S fertilization (Abstract).** Agron. Abstr., Am. Soc. Agron., Madison, WI, p. 220.
Abstract: Two lysimeters experiments demonstrated that N_2 fixation by subclover (*Trifolium subterraneum*) was increased when sulfur was applied. The experiments were designed to study the competitive effects between three forage species under S limited conditions. N_2 fixation was enhanced by S whether or not the added S produced significant yield responses. The percent of N in subclover coming from N_2 fixation was enhanced further when subclover was grown with associated non-legumes. Estimates of symbiotic N_2 fixation derived from the ^{15}N dilution method were highly correlated with those determined from the N difference technique ($R^2 = 0.97$). Sulfur applications increased soil N uptake as well as N_2 fixation, and this fact has to be considered in calculating estimates of N_2 fixation by total N difference.

4252. Shock, Clinton C., Milton B. Jones, William A. Williams, and D. Michael Center. 1983. **Effect of sulfur fertilization on three annual range species. I. Laughlin soil experiment.** Agron. J. 75:515-520.
Abstract: The fate of a single application of sodium sulfate and its effect on three range species grown alone and in pairs in free-draining lysimeters containing Laughlin loam soil (fine-loamy, mixed, mesic Ultic Haploxerolls) was monitored during two growing seasons. Plant growth responses to added S were small because the soil released considerable S during the course of the experiment, equivalent to more than half of the S application. However, the growth of subclover (*Trifolium subterraneum*) and its mixtures with filaree (*Erodium botrys*) and soft chess (*Bromus mollis*) was increased by S fertilization ($P = 0.06$). The botanical composition shifted towards subclover with added S. On the lysimeters where S was applied, subclover and filaree obtained more of their S from the applied fertilizer (55 and 55%) than did soft chess (44%). Total plant recovery of fertilizer sulfur in the first year was greater in pure stands of subclover (20%) than for soft chess (11%) and filaree (7%). Total sulfur uptake was greatest on S fertilized lysimeters of subclover or subclover plus filaree. Leachate losses of S in the first year were positively related to the amount of S applied and volume of leachate and negatively related to S uptake by the plants. In the second year leachate losses of S were positively related to the calculated S status of the soil at the end of the first year and negatively to plant S uptake. A greater leachate volume was lost from lysimeters containing filaree than containing soft chess or subterranean clover, and mixtures were intermediate. Leachate volume was not related to dry matter production. Sulfur application did not affect N uptake by the nonlegumes, but subclover N_2 fixation was increased by 60% during the first year. The percentage of subclover N coming from N_2 fixation was enhanced by the presence of non-legumes. Estimates of recovery of fertilizer S were significantly less by calculations based on ^{35}S than on total S differences suggesting that the labile ^{35}S is diluted in the soil solution by the release of nonlabeled S from decomposition of organic matter.

4253. Shock, Clinton C., Milton B. Jones, William A. Williams, and D. Michael Center. 1984. **Competition for S and N by associations of three annual range species in lysimeters.** Plant and Soil 81:311-321.
Abstract: Competition for S and N was studied on free draining lysimeters seeded to associations of three annual forages on Josephine loam (*Typic Haploxerults*), an important soil for revegetation to rangeland production. Forage yields increased and the botanical composition shifted toward subclover (*Trifolium subterraneum*) with added S. Sulfate uptake and plant S concentration were increased as a function of the S applied. Forage yields were related to plant S concentration and N:S ratios. Subclover and filaree (*Erodium botrys*) obtained a larger proportion of their S from fertilizer-S than did soft chess (*Bromus mollis*). Total S uptake was largely from the applied fertilizer, 39% at the intermediate S level and 78% at high S. The replacement series design of the experiment and the use of labeled S and N permitted calculation of competition coefficients for fertilizer S, total S, soil N, and total N uptake for the species in pairwise associations. Sulfur was the factor limiting to subclover where S was not applied, and N was the limiting factor to soft chess and filaree in mixtures with subclover at high S where subclover was able to fix most of its own N. In the mixture of soft chess and filaree, competition for S and N was about equally intense for both nutrients at all S levels, and filaree was dominant consistently. Comparison of two methods for estimating the fate of fertilizer S showed that differences in sulfur uptake and leachate losses over the controls provided significantly higher values for sulfur recovery than estimates based on the fate of ^{35}S.

4254. Shock, Clinton C., William A. Williams, Milton B. Jones, D. Michael Center, and Donald A. Phillips. 1984. **Nitrogen fixation by subclover associations fertilized with sulfur.** Plant and Soil 81:323-332.
Abstract: The effect of S fertilization on symbiotic N_2 fixation was measured with the ^{15}N technique and the N difference method in a lysimeter study using Josephine loam (*Typic Haploxurults*). Nitrogen fixation by subclover (*Trifolium subterraneum*) was strongly enhanced by added S. The association of soft chess (*Bromus mollis*) or filaree (*Erodium botrys*) with subclover increased the percentage of N in subclover that was fixed, with the result that N_2 fixation was increased beyond that due to the mere increase in subclover biomass. Nitrogen fixation estimates by ^{15}N dilution and N difference methods were highly correlated ($r^2 = 0.97$), and S fertilizer did not result in any significant differences in N_2 - fixation estimation by the two methods. Both methods were useful in distinguishing between soil N uptake and N_2 fixation where S applications produced highly significant increases in both uptake and fixation. Application of sulfur fertilizers to much annual rangeland has the potential to increase pasture productivity through enhanced N_2 fixation.

4255. Sidahmed, Ahmed E., Steven R. Radosevich, J. G. Morris, and W. L. Graves. 1978. **An assessment of goat grazing in chaparral.** Calif. Agric. 32(10):12-13.
Abstract: The browsing preference of Spanish goats during a limited summer period in a 0.2-ha plot of a 5-year-old chaparral fuel break was highly directed (about 80%) toward scrub oak and chamise. Grasses and forbs contributed about 20% of the total diet, while eastwood manzanita and cupleaf ceanothus appear to have negligible contribution. Further work into the effects of season and long-term grazing is needed for more comprehensive deductions.

4256. Sidahmed, Ahmed E., Steven R. Radosevich, James G. Morris, and Ling J. Koong. 1982. **Nutritive value of chaparral for goats grazing in fuel-breaks.** Calif. Agric. 36(5-6):12-14.
Abstract: Using goats for chaparral brush control it was found they preferred scrub oak the most and manzanita the least. However, when goats were forced to consume a diet high in manzanita, they collected plant parts of highest nutritive value. The goats discriminated against portions of the scrub with high cell wall content and low nitrogen. Tannins and lignin did not contribute significantly to the variation in *in vitro* dry matter digestibility. These results suggest that the level of nitrogen in the shrubs has a greater effect on digestibility than either lignins or tannins. Another explanation could be that immature browse is associated with high nitrogen and low cell wall contents.

4257. Spencer, K., J. R. Freney, and M. B. Jones. 1977. **Diagnosis**

of sulphur deficiency in subterranean clover. Sulphur in Agric. 1:12-15, 17.
Abstract: We investigated the effect of sulfur supply on the levels of sulfur fractions in plants and, in turn, on the values used for diagnostic purposes. While the probable significance of age and plant part has been recognized, their importance has not been quantified for subterranean clover (*Trifolium subterraneum*). Plant age, plant part, and maturity of plant part affect all 3 of the commonly used indices of sulfur status, but the N:S ratio is least affected by these factors. Selection of laminal tissue further minimizes the effects of plant age and tissue maturity, and this combination is recommended as the most useful for diagnostic interpretation when precise knowledge of plant age is lacking.

4258. Spencer, K., M. B. Jones, and J. R. Freney. 1977. **Diagnostic indices for sulphur status of subterranean clover.** Aust. J. Agric. Res. 28:401-412.
Abstract: The variations of total sulfur, sulfate sulfur, and total nitrogen/total sulfur ratio, $(N/S)_t$, in subterranean clover (*Trifolium subterraneum*) with age of plant, nutrient status, and plant part were studied in a glasshouse experiment on sulfur-deficient soil. The concentrations of total sulfur and sulfate sulfur in the plant increased with increasing sulfur supply and decreased with plant age or with supplemental nitrogen. Overall, the laminae contained a higher concentration of total nitrogen than the petioles; when the optimal concentrations for growth was present, the concentration in the laminae was approximately twice that in the petioles. In sulfur-deficient plants there was little difference between sulfate concentrations in laminae and petioles. In young sulfur-sufficient plants, higher concentrations were found in the petioles than in the laminae but this was reversed for older plants. With increasing sulfur supply there were bigger relative increases in sulfate than in total sulfur and the magnitude of both these fraction changed more in petioles than in laminae. In general, the $(N/S)_t$ ratio increased with age of plant or supplemental nitrogen, and decreased with increasing sulfur supply. The changes with age were smaller in the laminae than the petioles. Petioles had a higher ratio than laminae in sulfur-deficient clover, and a lower ratio where sulfur was adequate. Critical concentrations of total and sulfate sulfur in the tissue were lowered by extra nitrogen, fell markedly as the plant aged, but were not much affected by maturity of the plant part. The $(N/S)_t$ ratio changes less with all factors than the other two indices, and thus promises fewer problems in interpretation.

4259. Spencer, K., J. R. Freney, and M. B. Jones. 1978. **Diagnosis of sulphur deficiency in plants.** Pp. 507-514 *in:* Proc. 8th Int. Colloq. on Plant Anal. and Fertilizer Problems (A. R. Ferguson, R. L. Sieleski, and I. B. Ferguson, eds.), Auckland, New Zealand, Aug. 28 - Sept. 1. Information Series No. 134, New Zealand DSIR, Government Printer, Wellington.
Abstract: Test plants representing four species (wheat, oats, rape, and subterranean clover) were grown in sulfur-deficient soil to which 6 levels of sulfur had been added before sowing. In comparison with the customary indices of sulfur status (total S, sulfate S and N:S ratio), the proportion of the total plant S held as sulfate proved to be less affected by plant age and level of nitrogen supply. Critical values based on this proportional index could prove to be a useful guide to the sulfur status of plants generally.

4260. Stumbos, John. 1999. **Ranchers plan to protect water quality.** Calif. Agric. 53(3):4-6.
Abstract: North coast ranchers, vineyard managers, and private landowners, among others in California, are developing comprehensive water quality management plans for their properties. This progress report describes the Ranch Water Quality Planning Short Course developed by a multidisciplinary team of UC extension and research professionals. The inclusion of a field trip to the Hopland R & E Center as an integral part of the Short Course is described by John Harper, Mendocino Co. livestock and natural resources advisor. Class participants develop a working knowledge of the analytical tool called a "Sediment TMDL (Total Maximum Daily Load) Inventory and Monitoring Worksheet," which helps landowners document sources of erosion, geological processes at work, probably causes, and potential control measures. This report also describes the umbrella Rangeland Watershed Program, under which related field research on water quality is being conducted by UC in cooperation with state, federal, and regional agencies.

4261. Tate, Kenneth W., Barbara Allen-Diaz, Randy Dahlgren, John Harper, and Edward R. Atwill. 1999. **North coast rangeland watershed and water quality study.** Final Report to UC DANR Competitive Grants Program, 1998-99 Grant #0018. 7 pp.
Abstract: Four oak woodland research and demonstration watersheds were developed at the UC Hopland Research and Extension Center. Staff constructed and installed 3-foot H-flumes in each of the watersheds as the primary hydrologic measuring device. Automated stream flow monitoring and water quality sampling equipment was installed and calibrated at all flume sites. An automated weather station, located on site, will monitor rainfall, air temperature, soil temperature, relative humidity, wind speed, wind direction and solar radiation. A 2-3 year collection of baseline hydrologic, water quality, vegetation and soils data will be collected before a portion of the watersheds are subjected to land use treatments. Potential treatments include grazing management ("heavy" v. "moderate" v. no grazing) and/or prescribed burning. Development of manuscripts and monitoring guides on the characterization of seasonal and within storm flow and concentration patterns, evaluation of turbidity as an estimator of total suspended solid concentration, and development of water and nutrient budgets for oak woodland watersheds is planned using the data set. These watershed sites also serve as demonstration sites for extension of results as well as monitoring methods to landowners, managers, UCCE academics, regulators, and the interested public.


Jack Kelly Clark
Water flows in an ephemeral drainage following spring rains, April 1996

4262. Tietje, William D., and Robert H. Schmidt. 1988. **California's integrated hardwood range management program.** Trans. N. Am. Wildl. Nat. Res. Conf. 53:67-77.
Abstract: California's native oaks are a multivalued resource that predominate over 7.4 million acres (3 million ha) of mostly privately owned oak rangeland. Poor regeneration and increased removal of oaks threaten their distribution and abundance. Solutions to these problems are complicated by inadequate information and the need for the development and extension of alternative management strategies. Strong property-rights sentiments and enforcement costs render regulations an unacceptable solution. University of California,

together with California Division of Forestry, developed the Integrated Hardwood Range Management Program, an education and research program committed to improving oak regeneration and offering landowners economically sound alternative management strategies. The IHRMP is currently in operation and its success, and that of future programs like it, rests on whether it can be demonstrated that this innovative approach to a resource-management challenge can change attitudes and resource-management practices, without the need for regulations.

4263. Torell, Donald T., Alfred H. Murphy, William C. Weir, and R. Merton Love. 1956. **Improved pastures for lambs.** Calif. Agric. 10(5):5, 16.
Abstract: Comparison of lamb weight gains during the 1954-55 season at Hopland were made between ewes and their lambs grazed on improved pastures, versus ewes and lambs grazed on unimproved pastures. Improved pastures totaled 68 acres formerly used for many years to produce cereal hay. In the fall of 1952 it was cultivated and seeded to a mixture of hardinggrass, tall fescue, rose, subterranean, and crimson clovers, narrowleaf trefoil, burnet, and alfalfa. In the fall of 1954, 300 lbs per acre of 16-20-0 (nitrogen-phosphorus-potassium) fertilizer were applied by airplane to seeded pastures. Results of these trials confirm the contention that a program of range pasture improvement by seeding and fertilization will provide an abundance of highly nutritious early feed for lactating ewes and their lambs. Ewes can be maintained, without supplementation, on a diet sufficiently nutritious to provide the necessary milk supply to support their lambs. Twin lambs can be grown out without creep feeding, to sizes which compare favorably with single lambs. The increased carrying capacity resulting from this pasture improvement will relieve the burden carried by the unimproved range, making a more effective program of overall range management possible.

Guy E. Connolly

HFS staff members Brown San Diego and Chuck Vaughn conduct field work on range plot, Vassar Pasture, January 1975

4264. Vaughn, Charles E., Milton B. Jones, and J. E. Ruckman. 1979. **Effects of sulfur-coated urea on California annual grassland yield and chemical composition.** Agron. J. 71(2):297-300.
Abstract: Fall applications of N fertilizers on California annual grasslands are often accompanied by luxury N uptake, excessive N leaching losses, and N deficiencies the following spring. Sulfur-coated urea (SCU), a slow-release fertilizer, was applied to a grassland soil (Laughlin, fine-loamy, mixed mesic, Ultic Haploxeroll) to determine whether it could supply adequate N and S and eliminate problems encountered with more soluble N fertilizers. Urea (U), urea with 100-mesh elemental S (U + S), and two formulations of SCU were broadcast on resident annual grassland, dominated by annual bromes (*Bromus* spp.), wild oats (*Avena barbata*), broadleaf filaree (*Erodium botrys*), and clover (*Trifolium* spp.), in a climate with cool, rainy winters, and hot, dry summers. Forage yield and N and S uptake were measured seasonally in the first year and annually the following five years. Seasonal growth distribution was similar from all fertilizers in the first year. However, U + S was significantly more productive and gave greater herbage S uptake than the SCU's and U throughout the first growing season, and greater N uptake in the first winter. Residual studies suggested the long-term benefit of S fertilization; the U + S and SCU treatments were significantly more productive for the last five years. Residual N uptake responses were similar to the yields. Herbage S uptake was similar in the U and check treatments for the entire study. The more heavily coated SCU formulation gave greater S uptake than both U + S treatments in the fourth and sixth years after application. It was concluded that the SCU's were of no greater benefit than urea combined with fine S in fertilizing California annual grasslands. The slow release of N from SCU did not give any greater apparent residual N response. There was a long-term response to the larger particles of S in SCU, but it is questionable that this would justify the extra cost of the fertilizer.

4265. Vaughn, Charles E., and Milton B. Jones. 1980. **Soil phosphorus tests on California subclover-annual grass pastures.** Soil Sci. 130(6):307-313.
Abstract: We evaluated the phosphorus fertility of 19 typical, California, annual grassland, pasture soils by comparing nine soil P tests: total, Bray and Kurtz methods 1 and 2, two Olsen extractions (1:10 and 1:20 soil:extractant ratios) and the "North Carolina", Truog, Morgan, and Bingham methods. Soil P test results were correlated with subclover-annual grass forage production and P content in the field and in the greenhouse. Correlation of soil P with actual yields and P uptake was generally better in the field than in the greenhouse. Phosphorus in the Bray and Kurtz 1 and the Olsen 1:10 and 1:20 extracts gave the best predictions of field forage production (respectively, $r = 0.82$, 0.73 and 0.67; $P < 0.01$). The relative values of the various tests in predicting field forage P content were quite similar with actual yields. The Bray and Kurtz 1 method was the most precise ($r = 0.87$), and the Olsen extracts were also highly correlated ($P < 0.01$). Bray and Kurtz 1 extractable soil P accounted for about 67 percent of the variation in subclover-annual grass forage yield and about 76 percent of the variation in forage P content. These were about 14 percent higher than with the Olsen extractants. When we consider relative precision and facility (a 60-second extraction time), the Bray and Kurtz 1 method appears to be of greater potential value for routine testing of annual pasture soils in north-coastal California.

4266. Vaughn, Charles E., and Alfred H. Murphy. 1982. **Long-term effects of fertilization and sub-clover seeding on Northern California annual range.** J. Range Manage. 35(1):92-95.
Abstract: The long-term effects of P and S fertilizers and subclover seeding on northern California annual range production and composition were measured during a 20-year study. Following an initial calibration period, 2 pastures were seeded and fertilized; Pasture A prior to the 1968 growing season and Pasture B prior to the 1973 growing season. After treatment, Pasture A produced significantly more forage annually. It also produced significantly more winter forage, and winter and annual forage N than either of two adjacent untreated control pastures during the period from 1973 to 1979. This was due primarily to an increase in native legumes because subclover averaged only 7% of cover. Treatment on Pasture B gave similar responses, but the relative increases in forage production were larger (annual production increased about 2,000 kg/ha compared to 1,200 kg/ha on Pasture A) and winter forage N concentrations were significantly higher than on Pasture A. This was due to the greater subclover component (36%) on Pasture B. The significant increases in forage production and protein indicate that

subclover seeding and appropriate fertilization are practical ways of improving utilization of northern California annual range.

A. H. Murphy

Third annual field day at HFS, May 18, 1955

4267. Vaughn, Charles E., D. Michael Center, and Milton B. Jones. 1986. **Seasonal fluctuations in nutrient availability in some northern California annual range soils.** Soil Sci. 141(1):43-51.
Abstract: We studied the effects of climate and land-use history on seasonal variations in available soil nutrients at 6 northern California annual range sites. Available soil N, S, P, Ca, Mg, and K were measured monthly for 2 years. Seasonal fluctuations in inorganic N were similar for both years over all sites; levels and variations in N were highest during winter and early spring and lowest during summer. Relative levels of available S, P, and Ca were also higher early in the year and declined later in the growing season, although the patterns were much less pronounced. Exchangeable Mg and K fluctuations were generally inconsistent and relatively smaller. Sheep grazing on unimproved pasture significantly ($P < 0.05$) increased average levels of available soil N, S, Ca, and Mg and decreased P availability. Seeding subclover and fertilizing with P and S increased available N and S levels. Converting chaparral brush to grassland decreased the availability of Mg and K.

4268. Vaughn, Charles E., Milton B. Jones, and D. Michael Center. 1987. **Sulfur tests on northern California subclover-annual grass pasture surface soils.** Soil Sci. 143(3):184-191.
Abstract: The sulfur status of surface soils on 17 northern California subclover annual grass pastures was diagnosed with five soil S tests: total S, and the sulfate soluble in LiCl, phosphate, and 2 dilute acid solutions (Hoeft and Bray-1 methods). Test results were evaluated for their effectiveness in predicting pasture yield and relative response to applied S. First year yields were correlated significantly only with the dilute acid extract results ($r = 0.52$ and 0.76; $P < 0.05$ and 0.01 for linear regressions with the Hoeft and Bray-1 tests, respectively), indicating that more tightly sorbed inorganic and labile organic sulfate were important components of the pasture-available S on these soils. Both regression equations describing the relationship between first year yields and S extracted by the Hoeft and Bray-1 methods were significantly improved by inclusion of the soil organic P: total S ratio. The Bray-1 test equation was further improved by including soil sand and clay levels, and the Hoeft by including organic C levels. All terms had negative coefficients. Relative yields during the first year were not correlated with any of the S tests on these disked soils. During the second growing season, when soils were more stable, the Bray-1 method was useful in predicting pasture response to residual S fertilizer. A critical sulfate-S value of about 10 ppm was indicated and correctly identified S response on 12 of the 17 soils (70%).

4269. Williams, William A., J. V. Lenz, and Alfred H. Murphy. 1953. **Establishment of subclover.** Calif. Agric. 7(2):3,16.
Abstract: Establishment of subclover (*Trifolium subterraneum*) requires the inoculation of the seed with nitrogen-fixing bacteria. Fresh inoculum must be used and the seed must be properly insulated to insure against possible failure of a subclover stand because of a lack of sufficient numbers of the proper strain of nitrogen-fixing bacteria. The inoculum is available commercially and is mixed with water so it will adhere to the seeds. For 100 pounds of seed approximately 1 quart of water is needed. The inoculum-water mixture is poured on the seeds, and mixed until all seeds are coated. The seeds should be sown as soon as they are dry enough to run freely. Inoculation is most likely to be successful when seed is sown in moist soil and covered. Hazards to legume bacteria are exposure to sunlight, drying, and high temperatures.

4270. Williams, William A., J. V. Lenz, and Alfred H. Murphy. 1954. **Nature of beneficial effect of subterranean clover straw on establishment of subterranean clover.** Agron. J. 46(2):95-96.
Abstract: Subterraneum clover (*Trifolium subterraneum*) can produce large quantities of high quality forage on the rangelands of northwest California. Difficulty occasionally occurs in obtaining satisfactory stands, and it has been observed that the application of subclover straw can produce vigorous stands in these instances. Field experiments were initiated to simulate the beneficial effects of the straw by studying three factors considered to be primarily responsible for affecting establishment: 1) the viable seed in the straw; 2) the mulching effect; and 3) the nodulating bacteria contained in the straw. Seeding alone did not produce a satisfactory stand. Mulching at 2 different rates did not produce more healthy plants than unmulched plots. Inoculating the seed at planting with a commercial inoculum culture did result in many times more healthy plants than was obtained without inoculation. Inoculation plus mulching at a high rate gave a further increase in establishment. Subclover straw without any seeding did not produce as many plants, but did produce the highest percentage of effectively nodulated clover plants. The evidence strongly pointed to the acquisition of effective legume bacteria from subclover straw as being the primary beneficial effect. Yield data taken later in the season supported this conclusion.

4271. Williams, William A., D. J. Davis, and Milton B. Jones. 1974. **Growth of annual legumes on serpentine soils.** Pp. 404-408 *in:* Proc. XII Int. Grassland Congr., Moscow, U.S.S.R.
Abstract: Soils derived from serpentine rocks occur in many parts of the world and usually are associated with a vegetation of stunted shrubs and a sparse herbaceous understory which provide little protection from rapid runoff and erosion. The successful introduction of annual legumes on such soils benefits forage production, water yield, erosion control, wildfire fuel management, and large game habitat. In northern California, serpentine soils are very low in exchangeable calcium while having an excessively high amount of exchangeable magnesium, and also they are generally deficient in nitrogen, phosphorus, and sulfur and to a lesser extent molybdenum and potassium. The objective of this study was to evaluate the response of a number of annual legumes to additions of Ca and Mg on a serpentine soil. The Mg treatments were included to simulate serpentine soils with an even stronger Ca-Mg imbalance. Dry weight production was measured, and plant tissue was analyzed to aid in postulating physiological mechanisms of adaptation. The annual legume varieties demonstrated a wide range of tolerances to low Ca and high Mg. Hykon rose clover (*Trifolium hirtum*) was particularly outstanding. It produced higher yields without the costly addition of Ca fertilizers, and was also able to tolerate higher Mg levels as measured by dry matter production. Tissue analysis indicated that Hykon rose clover was able to selectively absorb Ca in preference to Mg in a high Mg environment. This physiological

characteristic was consistent among the varieties of rose clover tested here.


A. H. Murphy

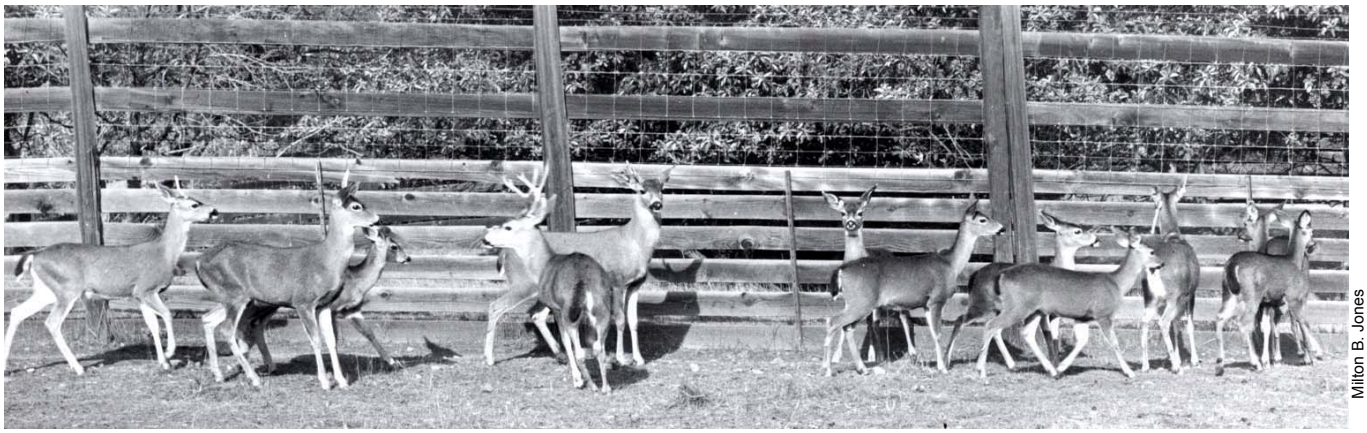
UC Davis agronomist Bill Williams at lysimeter, November 1962

4272. Young, James A., Raymond A. Evans, and Burgess L. Kay. 1971. **Response of medusahead to paraquat.** J. Range Manage. 24(1):41-43.

Abstract: Medusahead, *Taeniatherum asperum,* plants from 23 locations (including Hopland) were susceptible to paraquat at Davis, California but resistant to applications of this herbicide at Reno or Stead, Nevada. Differences in response were not due to ecotypic variability among the sources. At Stead during the summer of 1967, the summer-grown plants sprayed with 0.5 lb/a of paraquat showed more leaf burn than did winter-grown plants, though they largely survived the treatment. These plants over-wintered and were resprayed the next spring without apparent injury. The 1967 common garden at Stead, which did not germinate until the spring of 1968, also survived the paraquat treatment. Resistance or susceptibility to paraquat at the original collection site showed no apparent relation to response at Stead or Davis. There is no evidence that the differences in response to paraquat at the different locations involved ecotypic variability among various sources. However, a few of the sources were completely killed by the paraquat treatment at Davis. The differences in susceptibility between the cis- and transmontane populations is apparently due to differences in unidentified characteristics of the two environments.

4273. Zavon, Juliet A. 1982. **Grazing and fire effects on annual grassland composition and sheep diet selectivity.** M.S. Thesis, Univ. Calif. Davis. 41 pp.

Abstract: When germination begins on annual range in the fall, the quantity of dry plant residue present affects the species composition and herbage production of future growth. Two management practices, prescribed stocking and burning, attempt to control dry plant residue on the range in order to improve or conserve range vegetation. A study was conducted on a north coast California annual range to observe changes in sheep diets and selectivity, botanical composition, and herbage standing crop with combination of 2 stocking rates and three burning treatments. Stocking was moderate or heavy. Sixty yearling ewes were grazed at a rate of 2 or 3 animals per 0.135-hectare paddock, and paddocks were unburned or burned in summer 1 or 2 years previously. Between February and June paddocks were sampled 3 times to correspond with the beginning of spring growth, rapid growth, and peak standing crop. Botanical composition was measured by reading three 100-point permanent line-point transects for a total of 300 points per paddock, and herbage standing crop data were collected by clipping five, 0.1-m^2 plots in each of 24 paddocks. In addition, diet samples were collected with 4 esophageal-fistulated sheep in each of the 3 sampling periods. The botanical composition of each fistula sample was determined by identifying 200 points with a binocular microscope. Diet categories were grasses, filaree (*Erodium* spp.) other forbs and litter. Preference for each category was estimated by the ratio of its proportion in the diet to its proportion on the range. Grazing intensity did not affect either grasses or other forbs on the range although medusahead (*Taeniatherum asperum*), the primary component of undesirable litter accumulations, was greatly reduced by heavy stocking. Litter was more abundant at moderate stocking, and filaree was more abundant at heavy stocking. More forage was produced under heavy stocking than moderate stocking. Neither grazing intensity consistently altered the abundance of any of the dietary categories, although preference for litter was higher at heavy stocking. On the range the least litter occurred one year post-burn. Burning increased filaree, decreased grasses, including both medusahead and soft chess (*Bromus mollis*). The content of other forbs was relatively unchanged by burning. Herbage standing crop was lowest on the most recently burned plots. Sheep diets contained the least litter and the most other forbs one year post-burn, filaree was consumed the most on burned plots, and the more recent the burn, the less the sheep consumed litter. Although preference for filaree was never very great, it was highest 2 years post-burn, while other categories were not affected. Both the proportion of grass and filaree on the range declined over the 3 sampling periods. Other forbs were highest in the second collection, and litter was highest in the third. The standing crop of herbage available was roughly the same for each sampling. Sheep grazed the most grasses and other forbs in the second sampling period. Litter consumption declined in the second period and rose in the third, and filaree continually decreased in the diets over time. Selectivity for litter was highest at the first sampling and highest for grasses in the third. Selectivity for filaree and other forbs was relatively constant, low for filaree and high for other forbs. Burning reduced undesirable litter accumulations for one year, but also reduced certain valuable range grasses, whereas heavy stocking reduced litter without other negative effects. Judicious use of prescribed stocking appears to be a better way to manage the litter component of the range.



Milton B. Jones

5001. Allo, Andrew A., John H. Oh, William M. Longhurst, and Guy E. Connolly. 1973. **VFA production in the digestive systems of deer and sheep.** J. Wildl. Manage. 37(2):202-211.
***Abstract*:** Volatile fatty acid (VFA) levels and production rates were measured in the gastrointestinal tracts of black-tailed deer (*Odocoileus hemionus columbianus*) and domestic sheep (*Ovis aries*). In all animals, VFA concentrations were high in the ruminoreticulum (R-R) and the hindgut but low in the abomasum and duodenum. Zero-time rates of VFA production in the R-R and the caecoproximal colon (C-PC) were determined by incubating the whole organs for three hours and measuring the changes in VFA levels at 30-minute intervals. For two sheep on a pelleted grain-alfalfa ration, two rumen-fistulated sheep on a pelleted alfalfa ration, three range deer, and two captive deer on a pelleted grain-alfalfa ration, respectively, the average estimated caloric value of total VFA production in the R-R and C-PC was 993, 968, 512, and 236 kcal/24 hours, equivalent to 89, 59, 45, and 22% of maintenance energy requirements. VFA production in the C-PC contributed only 1% of maintenance energy requirements for deer and 5 - 9% for sheep. The relatively low VFA production for the captive deer was attributed to low feed consumption.

5002. Anderson, Frank M., Guy E. Connolly, A. N. Halter, and William M. Longhurst. 1971. **Simulation experiments with a biomanagement model of a deer herd.** Pp. 297-302 *in:* Proc. Ann. Symp. of Systems, Man, and Cybernetics Group, IEEE, Anaheim, CA. Technical Paper No. 3124, Oregon Agric. Expt. Stn., Corvallis, OR.
Abstract: A population dynamics model of the Mendocino County (California) deer herd has been computerized and tested. The birth-death process in this complex biosystem is modeled as a set of density dependent birth and death rate functions. The model is structured to permit detailed examination of the influence of selected hunting strategies on the age and sex structure of the deer herd and other aspects of deer management. In design of experiments for management purposes attention is focused both on the time path of outcomes and on the expected outcome at selected times after the initiation of the particular run. The model has been used to identify where additional information should be collected to improve the management of the herd and has indicated the usefulness, or deficiency, of current data collections. The output can be given an economic interpretation. Selected hunting strategies are presented. Results to date indicate that the simulation model can provide useful information on the interactions of the component parts of the biosystem and that similar models could be constructed for other complex biosystems such as forest and fishery resources.

5003. Anderson, Frank M. 1972. **Computer simulation of a biomanagement system - the Mendocino County deer population in California.** Ph.D. Dissertation, Oregon State Univ. 155 pp.
Abstract: A number of benefits and costs are associated with deer in Mendocino County. The benefits resulting from sport hunting are related to the size of the hunting kill, while the costs such as depredations on crops and forest tree seedlings depend on deer numbers. Variations in the hunting kill can affect both the positive and negative values of the deer population. This thesis describes computer simulation experiments to determine the response of the deer population to alternative hunting strategies.

5004. Anderson, Frank M., Guy E. Connolly, A. N. Halter, and William M. Longhurst. 1973. **Simulation experiments to evaluate alternative hunting strategies for a deer population.** Pp. 121-132 *in:* Workshop on Econ. Res. Related to Fish. Manage. NOAA Tech. Rep. NMFS Circ. 371 (A. A. Sokoloski, ed.), U.S. Dept. of Commerce, National Marine Fisheries Serv.
***Abstract*:** A population dynamics model of the deer herd in Mendocino County, California is presented. Environmental influences are modeled as density dependent birth and death rate functions. The computer program for this biomanagement model is outlined and validity checks devised to improve the model are discussed. The output shows the impact of selected hunting strategies on productivity, natural mortality, and other population characteristics. Tests of hunting strategies related to alternative management goals are summarized. Implications of computer simulation methodology for the management of wildlife and fish populations are discussed.

5005. Anderson, Frank M., Albert N. Halter, Guy E. Connolly, and William M. Longhurst. 1974. **A computer simulation study of deer in Mendocino County, California.** Tech. Bull. 130, Oregon State Univ. Exp. Stn., Corvallis, OR. 72 pp.
Abstract: This bulletin evaluates the benefit-cost comparisons for various hunting strategies depending on the objectives of the deer management program. The simulation model shows the results from eight different hunting strategies representing a range of feasible options in Mendocino County. The eight strategies were: 1) no hunting; 2) 25% legal buck kill; 3) 50% legal buck kill; 4) 25% doe kill; 5) 25% legal buck and 25% legal doe kill; 6) 50% buck, 15% doe and 80% fawn kill; 7) 25% legal buck, 15% doe, 5% spike and 5% fawn kill; and 8) 50% legal buck, 15% doe, 5% spike, and 5% fawn kill. Explains use of computer simulation model and its value to study effects of hunting on deer populations.

Guy E. Connolly

Captive research coyotes and a lamb investigate each other through a livestock fence, 1974

5006. Anonymous. 1998. **Management of livestock depredation: developing more selective control strategies.** P. 12 *in:* National Wildlife Research Center Highlights Report, Fiscal Year 1998. USDA APHIS Miscell. Publ. 1552, Denver, CO.
Abstract: Field research on coyotes at Hopland over a 5½-year period, assisted by UC Berkeley graduate students and student technicians, is summarized. Coyotes were radio-collared and tracked on Center property, while predation on the Center's research sheep flock was simultaneously monitored. These studies revealed that relatively few coyotes within the local population were apparently involved in killing sheep. Those responsible were primarily alpha pairs whose territories overlapped pastures containing sheep, especially lambs. This finding was supported by the fact that sheep killing often continued until one or more of the alpha pair was

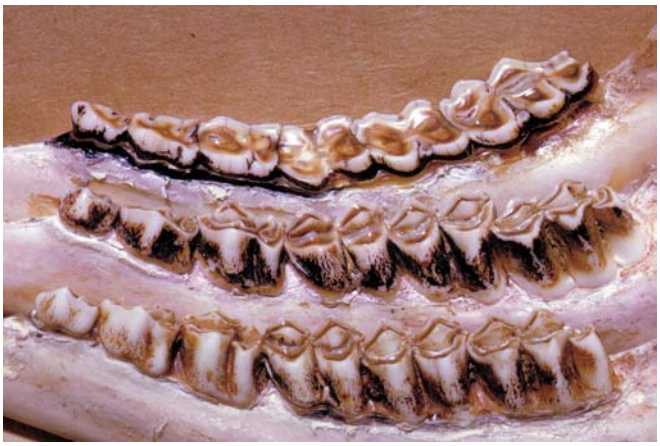
removed. Selective removal of sheep-killing coyotes, by use of the Livestock Protection Collar, was seen to effectively stop predation in multiple instances.

5007. Anonymous. 2001. **Selective targeting of adult territorial coyotes to manage sheep depredation: efficacy and methods.** P. 14 *in:* Innovative Solutions to Human-Wildlife Conflicts. National Wildlife Research Center Accomplishments 2001 USDA APHIS Miscell. Publ. No. 1585, Fort Collins, CO.
Abstract: Results of field studies on coyote control at Hopland are briefly summarized. Selective removal of territorial, breeding coyotes was conducted in the late 1990s. Breeding pairs were the primary predators of sheep, and they killed sheep only within or on the periphery of their territories. Removal of either or both members of a pair reduced or eliminated predation in that territory during the subsequent 3-month period. Sheep killing resumed sooner in territories that overlapped pastures with lamb than in those that did not. For territories with access to lambs, the average interval until killing resumed approximated the time it took for a replacement pair of coyotes to become established. Removal of breeding coyotes during the nonlambing season was not shown to reduce losses during the following lambing season. Although less than a third as many coyotes were removed during selective control as during "nonselective" control, lamb losses were significantly lower.

5008. Baker, Rex O., Gerald R. Bodman, and Robert M. Timm. 1994. **Rodent-proof construction and exclusion methods.** Pp. B-137 - B-150 *in:* S. E. Hygnstrom, R. M. Timm and G. E. Larson (eds.), Prevention and Control of Wildlife Damage. Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE.
Abstract: This chapter provides guidelines for making both residential and agricultural structures rodent-proof. The potential damage rats and mice can cause to structures and their components are reviewed, as are the physical capabilities of the commensal rodents. Common points of entry for rodents into buildings are noted, and methods for preventing rodent entry are given. The authors provide recommended exclusion methods for existing buildings as well as design considerations for new structures. Twenty-seven photos or line drawings are included as illustrations.

5009. Baker, Rex O., and Robert M. Timm. 1998. **Management of conflicts between urban coyotes and humans in southern California.** Pp. 299-312 *in:* Proc. 18th Vertebr. Pest Conf. (R. O. Baker and A. C. Crabb, eds.), Costa Mesa, CA. Univ. Calif. Davis.
Abstract: An apparent increase in coyote-human conflicts, notably attacks on humans, demonstrates that such incidents are not rare in California. The authors discuss coyote attacks on 53 humans, resulting in 21 instances of human injury, over the last decade. These illustrate repeated, predictable pre-attack coyote behavior patterns. Specific changes in human environments and in human behavior that have contributed to coyote attacks are discussed. Case histories of attacks reveal contributing factors and suggest appropriate corrective and preventative actions. Padded leghold traps have been the most effective and efficient tool in removing problem coyotes and changing the behavior of coyotes to fear humans in the urban environment. Long-term solutions will require changes in human behavior. Humans must come to view large mammalian predators as a potential hazard. Increased public education is needed to improve methods of landscape management, refuse disposal, care of pets, and recognition of the need for predator management.

5010. Barnes, Raymond D., and William M. Longhurst. 1960. **Techniques for dental impressions, restraining and embedding markers in live-trapped deer.** J. Wildl. Manage. 24(2):224-226.
Abstract: A technique was developed at the Hopland Field Station during the mid-1950s for taking dental impressions of black-tailed deer, allowing a permanent record of their teeth that can be compared to known-age jaws for more accurate aging. This proved superior to the previous methods of visually inspecting live-captured deer with the aid of a jaw spreader, flashlight, and dental mirror. The method is superior to that of another that was recently published, and it can be used at the trapsite by one person. It can be equally useful at checking stations where hunter-killed deer are aged. In live-trapping deer at Hopland, we have noted that a certain amount of mortality resulting from self-inflicted injuries appears to be almost inevitable. Many injuries are to the lower spinal column, resulting in paralysis of the hindquarters. A device that restrains deer with its legs fully extended prevents the deer from exercising much force in its struggle to escape. We describe and illustrate a restraining bar that has been used successfully on more than 60 deer during the 1959 trapping season and has restrained them more effectively, safely, and for longer periods of time than had previously been possible using hobbles alone. Deer trapped at Hopland for the past 5 years have been identified prior to release by marking them with a system of round aluminum cattle ear tags as well as with ear cuts, and with painted bells bearing individual designs. While this system has proved adequate for purposes of field identification, we have noted that some deer lose their eartags and when encountered as range carcasses or hunter kills, are usually unidentifiable. Further, we have not attached bells to most bucks, as the straps attaching the bell become too tight when the buck's neck swells during the rut. To prevent lost data, a supplementary marking system using a small plastic cylinder approximately 16 × 2 mm bearing an etched serial number has been used. It is imbedded beneath the skin close to the base of the ear, using a small applicator tool with a hollow needle furnished by the manufacturer. This system, developed for identification of registered livestock, should be useful on other big game as well as on rabbits, the larger rodents, and possibly on certain bird species.



Guy E. Connolly

Jawbones taken from deer provide a means of determining herd age composition, August 1973

5011. Barnes, Raymond D. 1966. **Natural reproduction, superovulation and insemination of black-tailed jackrabbits and the transfer of their ova to domestic rabbits.** Ph.D. Dissertation, Univ. Calif. Davis. 53 pp.
Abstract: Evidence from the literature of transplantation biology and mammalian embryology has been presented in support of the hypothesis that the mammalian conceptus should be regarded as a successful homograft. Arguments have been reviewed regarding the mechanism which protects the embryo from its natural mother's immune system. Intraspecific ova transfers were cited in further support of the effectiveness of the protective, fibrinoid layer seen in electron micrographs of the trophoblast. In this study, ova recovered in early cleavage stages from artificially inseminated jackrabbits were

transferred to domestic rabbits in order to test the hypothesis that the survival of such heterotransplants could be influenced by techniques borrowed from transplantation biology. One of the four methods employed has provided limited evidence that such an hypothesis may be valid. In one instance two jackrabbit embryos survived long enough in their foster rabbit mother to elicit decidual tissue and to present, on the fourteenth day of gestation, uterine swellings which gave every appearance of living embryos. In a second instance a single swelling was observed on the eleventh day following ovulation. In all, 67 jackrabbit ova in early cleavage stages were transferred to rabbits in fifteen separate trails. Development observed in comparable to that reported by Warwick and Berry (1949) for goat embryos recovered from sheep. It is considerably less than they reported for the reciprocal transfer. One sheep embryo recovered at 45 days was alive when the dam was sacrificed, but none of the 31 transfers which they made over an eight-year period came to term. No other transfer of ova between species has resulted in survival of embryos beyond the time of implantation. Transfers have been reported between several laboratory rodents, between rabbits and sheep, and between cattle and rabbits. The development obtained by Warwick and Berry of sheep in goats and goats in sheep was, in each instance, comparable to the development they observed in hybrids of the same animals. Whether or not this is a coincidental observation must remain for future work to show. It may be worth noting, however, that hares and rabbits have never been successfully hybridized even though several cleavages follow fertilization of rabbit ova with hare sperm. Adams (1957) has also reported separately on attempted hybridization of the two genera, and Castle (1925) reviewed the evidence for and against the possibility from a genetic viewpoint. The obvious implication that hybridizing species of mammals might be expected to carry transferred ova to term is not as promising as it might seem at first thought. Tigers and lions, which are among the few mammals known to hybridize, are unsuitable experimental subjects. Strangely, the horse-ass transfer has never been attempted, but gives more promise of success than any other which might be suggested. Among wild species hybridization is suspected in the genus *Odocoileus* between white-tailed mule deer, but the evidence remains circumstantial. Marsupials offer an opportunity to separate the influence of nidation on survival of transferred ova from other mechanisms, since they do not form decidual tissue. The resolution of the questions surrounding the immune relations of embryo and mother will advance significantly our knowledge of mammalian reproduction. Placentation, as an evolutionary step, is an unfinished business, if we may judge from the number of solutions to the problem still competing for selection. The success of mammals hinges on this adaptation to no small degree and somewhere in every mammal's physiology there must be a key to the problem of the fetus as a homograft. That key may well fit other practical problems of tissue transplantation and immunobiology.

5012. Barnum, Douglas A., Daniel B. Fagre, Charles Crouse, Nan Pec, Rex E. Marsh, and Walter E. Howard. 1981. **Hopland bait-pouch tests.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Twin Falls, ID, Aug. 11-12. 1 p.
Abstract: Progress in efforts to develop bait posts as a means of delivering chemical compounds to coyotes (*Canis latrans*) are summarized. Plastic pouches containing corn syrup and rhodamine B dye encased in a pouch made of lawn chair webbing were tested in the field. The attractant applied to the pouches was the W-U lure (trimethylammonium decanoate plus sulfide additives), because it was previously seen to be an effective attractant that also elicits from coyotes a biting response. While captive coyotes had previously been attracted to and vigorously bit and punctured these devices, only one confirmed bite and two possible visits occurred in field tests totaling approx. 5,000 exposure-days. Information received from Animal Damage Control personnel indicated that the W-U lure as used might have been too potent for wild coyotes, thus acting as a mild repellent. Subsequent pen tests with captive coyotes showed that W-U lure could be diluted into lard, which acts as a slow-release mechanism, with no reduction in attractancy. Exposure of the plastic pouches within a small pouch of rabbit skin was tried in an attempt to increase coyote biting of these devices.

5013. Barnum, Douglas A., Daniel B. Fagre, and Walter E. Howard. 1982. **Liver extracts as potential lures.** Pp. 9-10 *in:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Waco, TX, Aug. 10-11.
Abstract: Sheep liver extract (SLE) was compared to other compounds attractive to coyotes, such as trimethylammonium decanoate (TMAD) and Carman's Distance Call Lure (CDCL). It elicited 76% as much of a response as CDCL, the best attractant known to date. Further, it elicited the most biting response of any compound tested not mixed in a carrier. Pork liver extract was found to be significantly more effective in attracting coyote than were SLE or beef liver extract; all of the liver extracts elicited significant licking-biting response. Four fractions of SLE were evaluated; the phenolic fraction elicited 2.5 times the response that whole SLE did. Further chemical analysis and behavioral testing is needed to identify the most attractive constituents or mixtures.

5014. Barnum, Douglas A., Daniel B. Fagre, and Rex E. Marsh. 1982. **Hopland tests of bait delivery devices.** Pp. 14-16 *in:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Waco, TX, Aug. 10-11.
Abstract: Bait delivery devices, packets of syrup encased in rabbit skin sheaths, placed on Hopland Field Station property from July through October 1981 were used to evaluate various coyote attractants. Wild coyotes responded most frequently to Carman's Distant Call Lure (CDCL), a commercial product. However, devices scented with W-U lure experienced a great rate of "take" and appeared to be more coyote-specific. This is significant, inasmuch as prior testing had shown summer to be the season when coyotes show least interest in W-U lure. The data indicate W-U is at least as attractive as synthetic fermented egg (SFE), the standard attractant formerly used in coyote scent station lines by the U. S. Fish & Wildlife Service. Coyotes attracted to the devices broke the syrup packets to ingest their contents. However, small mammals also were attracted to the devices, probably due to lard within the attractant mixture and the rabbit skin. Design modifications that eliminate the rabbit skin and lard were accomplished and have alleviated the problem of attracting non-target mammals, thus making the devices more coyote-specific. Delivery devices including the re-designed "bait delivery units" as well as Coyote Lure Operative Devices (CLODs) were field-tested at the U.S. Sheep Experiment Station in June 1982 with semi-wild captive coyotes. Preliminary results indicate a high rate of visitation for both the units and the lure used, W-U diluted in glycerine. The syrup reward within the units builds a positive odor-reward association in coyotes.

5015. Blejwas, Karen, and Michael M. Jaeger. 1997. **Turnover, territories, and sheep depredations in an exploited coyote population (Abstract).** P. 3 *in:* Abstracts, Ann. Conf., West. Sect. Wildl. Soc., San Diego, CA.
Abstract: Territorial, breeding adult coyotes (*Canis latrans*) are responsible for the majority of coyote depredations on domestic sheep, indicating that selective control may be more effective than blanket control efforts. Furthermore, population reduction efforts may be futile when attempted over a small area. We examined the coyote replacement process following a period of intensive control on the Hopland R & E Center, focusing on the lag times until breeding territories were reestablished and sheep depredations resumed. The

control effort resulted in the removal of 34 coyotes between fall 1994 and fall 1995, including 3 of 4 known breeding pairs and 10 of the 11 radio-collared study animals. Research trapping resumed following the cessation of operational control in November 1995, with 22 new animals collared to date. By late spring, the territorial vacancies had been filled, with 4 new territories replacing the original 3, and at least 2 of those producing pups. Three of the territories had access to lambs, and lamb depredations occurred in all 3. Depredations during the 1996 lambing season were high. The single territory to survive the control operation remained stable throughout the study period.

5016. Blejwas, Karen M., Michael M. Jaeger, and Dale R. McCullough. 1997. **Reducing coyote predation on livestock through selective control (Abstract).** P. 76 *in:* Abstracts, 4th Ann. Conf., The Wildlife Soc., Snowmass Village, CO.
Abstract: Population reduction over small, ranch-sized areas is one of the most common responses to coyote (*Canis latrans*) depredations on livestock, a strategy based on the assumption that reducing coyote numbers will also reduce coyote livestock losses. Research has shown, however, that territorial, breeding adults are responsible for the majority of depredations, suggesting that selective control may be a more effective approach to the predation problem. Furthermore, despite the widespread reliance on broadcast control, there is little information available about how local coyote populations respond to such exploitation. We are in the final year of a 3-year study investigating the territorial dynamics of a local coyote population under three different control regimes: no control, intensive broadcast control, and the selective removal of problem individuals. Our objectives were to determine how quickly breeding adults removed by control are replaced and breeding territories reestablished, and to evaluate the effectiveness of selective control at stopping predation. Territorial, breeding adults were replaced quickly and the reestablishment of breeding territories was essentially complete by the onset of the next breeding season. Territories remained stable as long as the breeding pair remained intact, while territorial shifts following the loss or acquisition of a mate were common. Selective control was effective at stopping predation within that coyote's territory during the non-lambing season, and preliminary data from the current lambing season indicate that the selective removal of problem coyotes at the beginning of lambing may stop predation during the lambing period as well.

5017. Book, Steven A. 1969. **Fallout Cesium-137 accumulation in two subpopulations of black-tailed deer (*Odocoileus hemionus columbianus*).** M.S. Thesis, Univ. Calif. Davis. 61 pp.
Abstract: Uncontrolled nuclear reactions from weapons tests have released a number of radioactive fission products into the atmosphere. Of these radionuclides, ^{137}cesium, ^{90}strontium, and ^{131}iodine are easily incorporated into terrestrial and aquatic ecosystems because of their metabolic similarity to the required elements potassium, calcium, and stable iodine. These biologically important fallout components remain for times sufficient to subject contaminated animals and plants to doses of ionizing radiation. This study was undertaken to investigate various parameters influencing the uptake of ^{137}Cs in a wild population of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) at the Hopland Field Station. The variation in ^{137}Cs body burdens of deer living in relatively close proximity yet occupying different elevational habitats was studied in relation to rainfall, type and availability of forage species, foliar contamination by the radionuclide, and dietary preferences. Results indicated the following: The data did not show any statistically significant variation in ^{137}Cs concentrations in rumen contents and muscle, although samples collected in winter (February-March) contained more ^{137}Cs. Rumen contents contained greater concentrations of ^{137}Cs than did muscle. Rumen contents and muscle of deer from oak woodland contained significantly higher concentrations of ^{137}Cs than samples from deer of the chaparral ($P < .01$). Differences in ^{137}Cs concentration reflect differences in diet. Ingested lichens appear to contribute appreciably to the ^{137}Cs body burden of oak woodland deer.


Guy E. Connolly

Deer silhouetted on the horizon, Summer 1979

5018. Book, Steven A., Guy E. Connolly, and William M. Longhurst. 1972. **Fallout ^{137}Cs accumulation in two adjacent populations of northern California deer.** Health Physics 22:379-385.
Abstract: Fallout ^{137}Cs was determined in rumen contents and muscle from 68 wild Columbian black-tailed deer (*Odocoileus hemionus columbianus*) collected over 2 years near Hopland, CA. Rumen contents only were obtained from 20 additional animals. Variations in ^{137}Cs burdens of deer living in close proximity within oak woodland and chaparral habitats were studied in relation to food habits and foliar contamination by the radionuclide. Because of dietary differences, samples from deer collected from the oak woodland contained higher concentrations of ^{137}Cs in all seasons than did samples from deer living in the chaparral. Oak woodland deer ate appreciable amounts of lichens at all seasons; these lichens contained up to 140 times the ^{137}Cs activity of other forage.

5019. Brock, Elbert M. 1958. **Some prey of the pygmy owl.** The Condor 60(5):338.
Abstract: Prey species of the pygmy owl (*Glaucidium gnoma*) included the meadow mouse (*Microtus californicus*), deer mouse (*Peromyscus maniculatus*), Jerusalem cricket, and Nuttall's woodpecker (*Dendrocopos nuttallii*).

5020. Brownlee, Robert G., Robert M. Silverstein, Dietland Müller-Schwarze, and Alan G. Singer. 1969. **Isolation, identification and function of the chief component of the male tarsal scent in black-tailed deer.** Nature 221(5177):284-285.
Abstract: The tarsal scent of black-tailed deer is of central importance in social behavior. Deer in an established group smell each other's tarsal tuft occasionally. When a strange deer approaches the group the frequency of tarsal smelling increases. The newcomer never checked the tarsal tuft of any of the established deer. Fawns recognize their mother by sniffing her tarsal organ. In adult bucks, the erection and rhythmical movements of the tarsal hair tuft and exposure of its scent are part of the threat posture. The major component of the buck tarsal scent is *cis*-4-hydroxydodec-6-enoic acid f-lactone. The γ-lactone functions as part of a complex stimulus pattern. Pheromone responses in mammals probably result from complex stimuli.

5021. Case, Ronald M., Robert M. Timm, Patrick J. Hegarty, and Daryl D. Fisher. 1988. **A decision making tool in animal damage control: the Plains pocket gopher (Abstract).** *In:* Abstracts, Third

Biennial Nat. Workshop on Micro-computer Applications in Fish and Wildlife Programs, Stateline, NV, Sept. 27-30.
Abstract: The plains pocket gopher (*Geomys bursarius*) is a squirrel-sized rodent that burrows and lives under the surface of the soil and feeds on plants such as alfalfa and grasses in pastures and rangelands. The pocket gopher is a nuisance to agricultural producers and often causes significant economic loss. The essence of this user-friendly program is to estimate the economic liability of the pocket gopher's presence in relation to costs of control and also to estimate whether control of pocket gophers is economically justified. The model forces the user to consider several means of control and whether control is economically justified, all in the spirit of Integrated Pest Management. The program can be run with programmed default values for several variables or the users can easily input their own values that pertain to a specific operation. We believe this model presents the users with realistic management options and teaches while examining the interactions among forages, pocket gophers, and various pocket gopher control strategies.

5022. Casler-Fagre, Ann, Daniel B. Fagre, and Walter E. Howard. 1980. **Development of coyote pup odor responses.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," North Bend, OR, Aug. 19-20. 5 pp. + figs.
Abstract: Results of a pilot study which examined the development of coyote pups' responses to odors are summarized. Six captive, hand-reared coyote pups detected and discriminated among odors during their first month of testing, and by the third month they demonstrated stable and significant odor preferences. As opposed to adults, pups preferred the odor of whole urine over a concentrated urine fraction, and they were less attracted to synthetic fermented egg. Whereas adult male coyotes prefer estrous urine fractions during breeding season, pups did not exhibit this pattern very clearly, if at all. Time spent at odors by pups increased from 22% as much time as spent by adults (during the first month) to 94% as much time by their 12th month. Rub-rolling behavior was noted as early as 6 weeks of age and appeared to be an innate response to certain odors. Scent-marking and ground scratching (scraping) did not begin until 3 to 9 months of age and neither behavior was very prevalent, even in 1-year-old animals. It was observed that the more dominant pups showed more active interest in odors, and at a younger age.

5023. Conner, Mary M. 1995. **Identifying patterns of coyote predation on sheep on a northern California ranch.** M.S. Thesis, Univ. Calif. Berkeley. 61 pp.
Abstract: The hypothesis that only a few individuals among a population of predators are responsible for most livestock killing was investigated by examining coyote (*Canis latrans*) predation on sheep (*Ovis aries*) with respect to: 1) spatial and temporal patterns of predation, 2) the proportion of coyotes that killed sheep, and 3) coyote control efforts. This study was conducted on the University of California's 2,168-ha Hopland Research & Extension Center (HREC), which maintains over 1,000 breeding ewes and produces lambs yearly. Historical records from 1981 to 1994 of sheep availability and location, and of predator kills, were analyzed for killing patterns. In addition, radio-telemetry data from 14 coyotes tracked from September 1993 through August 1994 on HREC were analyzed to evaluate predation by individual coyotes. The most important factor influencing coyote predation was the availability of lambs. Times and locations of highest predation rates coincided with the presence, but not necessarily the number, of lambs. The number of ewes killed and ewe predation rates were lower when lambs were present, but showed no relationship to the number of lambs. The number of lambs killed leveled off in January, although the number of lambs available increased through February. Data suggested that only some coyotes were killing, and may have been excluding other coyotes from killing lambs. Forty-four coyote kills occurred during the radio-tracking sessions. Not all of the radio-collared coyotes killed sheep, and those who killed varied in their likelihood of making a kill. Seven (50%) of the radio-collared coyotes were not suspects in any kills. Twenty-eight of the 44 kills that occurred during radio-tracking sessions had one or more of the radio-collared coyotes as a suspect. Of these 28 kills with a suspect, four (28%) of the radio-collared coyotes were responsible for 82% of the kills, while the other coyotes were responsible for the remaining 18% of the kills. Although all of the coyotes suspected for killing sheep were adults, there were not enough data to characterize the sheep-killing coyotes. Of the four coyotes responsible for most (82%) of the killings, one was thought to be transient and three were resident on HREC, and one was female and three were male. Overall, there were four female coyotes and three male coyotes suspected of killing sheep; female coyotes were implicated in 28% of the kills, male coyotes were implicated in 54% of the kills, and male/female pairs were implicated in 18% of the kills. Further research is needed: 1) to determine the characteristics of "problem" coyotes, 2) to develop control or protection efforts selective towards "problem" coyotes, 3) to determine the effect of removing "problem" coyotes on depredation patterns, and 4) to determine the length of time over which the removal reduces sheep killing. Traditional coyote control efforts at HREC have not been effective at reducing depredation within or between years. Lack of success within years may be due to lack of selection for problem animals, and the differential removal of young, non-killing animals. Lack of success between years may be because past control efforts have not reduced the coyote population levels on HREC due to free immigration from a large reservoir of coyotes in surrounding areas, and through reproductive compensation in the resident coyote population.

5024. Conner, Mary M., Michael M. Jaeger, and Theodore J. Weller. 1995. **Identifying the coyote who kills on a northern California sheep ranch (Abstract).** P. 27 *in:* Abstracts, 2nd Ann. Conf., The Wildlife Soc., Portland, OR.
Abstract: We investigated sheep-killing coyotes (*Canis latrans*) by looking at coyote killing patterns 1) in space, 2) in time, 3) by individual coyotes, and 4) by evaluating control efficacy for removing the habitual predators. We tested the hypotheses that sheep kills were clustered in time, that sheep kills were clustered in space, and that all coyotes had an equal probability of making a kill. Fifteen years of historical records and recent radiotelemetry data from 13 coyotes tracked September 1993 through August 1994 were analyzed to test these hypotheses. This study was conducted on a 2,168-ha Univ. of California wool growing research station that maintains 900 - 1,500 mature ewes, and produces 1,000 - 2,500 lambs yearly. Kills were clustered in time, and 13 groups of kills were defined as clusters during the radiotelemetry part of the study. Kills were clustered in space, but the pastures with high kill selection changed within years and between years. Forty-two coyote kills occurred while we were radio tracking. Six of the tracked coyotes were never found close to any kills, and one coyote was near only one kill. Twenty-five of the 42 kills that occurred had ≥1 of the radio-tracked coyotes as a suspect. Of these 25 kills, 31% of the tracked coyotes were responsible for 88% of the kills. For 6 of the 7 kill clusters with a suspect, one coyote was responsible for all killing in the cluster. Standard control procedures removed 13 coyotes from the station during the radiotelemetry study. None of the identified killers were removed; there was a high proportion of young coyotes removed.

5025. Conner, Mary M., Michael M. Jaeger, Theodore J. Weller, and Dale R. McCullough. 1998. **Effect of coyote removal on sheep depredation in northern California.** J. Wildl. Manage. 62(2):690-699.
Abstract: We used 13 years of historical data to investigate effects of coyote (*Canis latrans*) removal on depredation of domestic sheep. The 2,168-ha study area maintained >1,000 breeding ewes that

produced lambs yearly. Records from 1981 through 1994, which included numbers of sheep, numbers of sheep known killed by coyotes, known numbers of coyotes removed, and annual numbers of trapper hours were summarized and analyzed on a yearly, seasonal, and monthly basis. We used regression analysis and found that annual, seasonal, or monthly depredation losses were not correlated with number of coyotes removed. Both annual number of lambs killed and number of coyotes removed were positively correlated with number of trapper hours. We used a cross-correlation analysis to detect any relation between coyote removal and subsequent depredation losses at all monthly intervals from 1 to 24 months. We found a trend of low negative correlation between depredation losses and number of coyotes removed for lags of 2-12 months, suggesting some reduction of sheep killing due to control efforts. Low correlations within years may be due to inconsistent removal of depredating coyotes while removing primarily young, nondepredating coyotes. Lack of correlation between years may have occurred because past control efforts have not had a lasting reduction on coyote density due to immigration, the compensatory nature of control efforts on coyote mortality, reproductive compensation in the resident coyote population, or all 3 factors.

Guy E. Connolly

At Hopland, studies of black-tailed jackrabbits have involved methods of age determination, as well as their role as reservoirs of disease

5026. Connolly, Guy E., M. L. Dudzinski, and William M. Longhurst. 1969. **The eye lens as an indicator of age in the black-tailed jack rabbit.** J. Wildl. Manage. 33(1):159-164.
Abstract: The eye lens weight-age relationship in 44 known-age black-tailed jack rabbits *(Lepus californicus*) reared at Hopland, California appeared significantly different from that reported from a Kansas population. Even though the precision of estimates of ages of jack rabbits based upon lens weight decreases as age increases, the lens weight technique of age estimation is preferable to the epiphyseal closure technique.

5027. Connolly, Guy E., M. L. Dudzinski, and William M. Longhurst. 1969. **An improved age-lens weight regression for black-tailed deer and mule deer.** J. Wildl. Manage. 33(3):701-704.
Abstract: Previously published eye lens weight-age data from known-age Columbian black-tailed deer (*Odocoileus hemionus columbianus*) and Rocky Mountain mule deer (*O. h. hemionus*) were described by a linear regression model. Mule deer have significantly higher lens weights than black tailed deer of a similar age although the rate of lens growth with age does not differ between the two subspecies. Sex differences were not apparent. Although deer over two years old cannot be aged to the nearest year from their lens weight with 95% confidence, the method may provide better age estimates for deer under a year of age than can be obtained by other techniques. Attempts to age deer collected at Hopland, California by examination of cementum annuli in incisors gave poor results.

5028. Connolly, Guy E. 1970. **A population model for deer on the Hopland Field Station, Mendocino County, California.** M.A. Thesis, Sonoma State College. 54 pp.
Abstract: The average numbers of black-tailed deer (*Odocoileus hemionus columbianus*) on the 5,000-acre Hopland Field Station from 1964 through 1966 were calculated from herd composition, hunter kill, carcass examination, trapping, and autopsy data. Herd composition counts indicated average October ratios of 17 legal bucks, 17 spike bucks, and 67 fawns per 100 does. Two estimates of October population were calculated from these ratios– one based on the age composition of the legal buck kill and the other on replacement of legal buck mortality. The average of these two estimates was considered to be the most reliable estimate of the October (post-hunting) population, and was adjusted for mortality and natality data to obtain estimates for April (pre-fawning), May (post-fawning), and July (pre-hunting). Minimum populations of 740, 690, 600, and 480 deer in May, July, October, and April respectively appeared to be required to support the annual known mortality of 41 legal bucks during the 3-year study period, assuming that the average birth rate, sex and age composition, and mortality ratios in the population were accurately determined. These estimates indicate an annual mortality rate of 35%. The mortality rate attributable to hunting of legal bucks during the regular deer season was estimated to be 5%, while an additional 10% was removed by trapping and collecting for research purposes. This annual man-caused mortality, amounting to slightly less than half of the total estimated mortality, appears to stimulate a higher fawn survival rate than that observed elsewhere in Mendocino County where legal hunting is limited to adult males. It is suggested that deer populations in this area can sustain much higher harvest levels than those currently achieved by the exclusive hunting of adult males.

5029. Connolly, Guy E., Frank M. Anderson, William M. Longhurst, and Albert N. Halter. 1971. **A computer simulation model for evaluating deer hunting strategies.** Pp. 1-9 *in:* Proc. Ann. Conf., Calif.-Nev. Sect., The Wildl. Soc. and Calif.-Nev. Chap., Am. Fish. Soc., West Sacramento, CA, Jan. 29-30.
Abstract: A population dynamics model of the deer herd in Mendocino County, California, is presented. Environmental influences are modeled as density-dependent birth and death rate functions. The development of the model and preparation of input from herd composition, hunter kill, productivity and other field data are discussed. The output shows the impact of selected hunting strategies on productivity, natural mortality, and other population parameters. Tests of alternative hunting strategies are summarized. Maximum yield will be achieved with a hunting removal of 20-25% of the does, 15-30% of the fawns, and over 50% of the bucks annually. Population size is not affected by buck hunting but decreases as doe hunting increases. The model can be applied to other big game populations without major alterations.

5030. Connolly, Guy E. 1974. **The politics of wildlife management in California.** Pp. 101-105 *in:* Trans. West. Sect. Wildl. Soc. and Am. Fish. Soc., Monterey, CA, Jan. 31 - Feb. 1.
Abstract: Resident wildlife is managed for the people of California by a complicated political system which includes the wildlife resources, public, legislature, governor, county supervisors, federal government, land management agencies, Fish and Game Commission, Fish and Game Department, Wildlife Conservation Board, and colleges and universities. Biologists make none of the important management decisions, but are limited to technical, advisory, and educational roles. The political system will produce biologically sound management only if the people demand it.

Biologists have an ethical commitment to management based on scientific principles, and must develop public support in order to meet that commitment.

5031. Connolly, Guy E. 1974. **Responses of coyotes to coyote urine and other scents.** Pp. 63-65 *in:* Proc. Ann. Mtng., Tech. Comm. West. Res. Proj. W-123 "Evaluating Management of Predators in Relation to Domestic Animals," Cheyenne, WY, Sept. 9-10.
Abstract: Coyote urine collected from captive animals at Hopland was fractionated by extraction with either, NaOH, and HCl. Responses of captive coyotes to these odors were observed, and the types of behavioral response categorized and recorded. The frequency and intensity of response was taken as an indication of the relative attractiveness of each urine fraction or other test odor. Urine from coyotes fed on dog food appeared somewhat less attractive than urine from coyotes fed on jackrabbit or ground squirrel. A number of other odors tested appeared equally or more attractive as compared to urine or urine fractions.


Guy E. Connolly

Research associate Guy Connolly with coyote taken from HFS property, November 1970

5032. Connolly, Guy E., and William M. Longhurst. 1975. **The effects of control on coyote populations.** Div. Agric. Sci. Bull. 1872, Univ. Calif. 37 pp.
Abstract: According to a model developed to simulate coyote population dynamics, the primary effect of killing coyotes is to reduce the density of the population thereby stimulating density-dependent changes in birth and natural mortality rates. Tests of varying levels of control kills showed that a coyote population can maintain itself and even increase its numbers except at the very highest levels of control. If 75% of the coyotes are killed each year, the population can be exterminated in slightly over 50 years. Birth control combined with killing coyotes directly reduced both the breeding and maximum populations more than when either method was used separately. However, birth control is not yet feasible for field operations. In this model, coyote populations reduced by intensive control recovered to precontrol densities within three to five years after control was terminated. Under current conditions, considering the restrictions placed upon control methods, coyote densities probably cannot be significantly reduced except in limited geographical areas. The yearling pregnancy rate and the mean litter size are probably the best criteria for indicating the level of control, although the proportion of yearlings in the breeding population, the proportion of pups in the control kill, and the ratio between the control kill and breeding population also vary with the intensity of control. Coyote control data from Mendocino County, California, were compared with the model output. The existing county control program does not appear to affect overall coyote numbers but locally it may be stimulating the rate of reproduction.

5033. Connolly, Guy E., and William M. Longhurst. 1975. **Deer production at Hopland Field Station.** Calif. Agric. 29(6):8-9.
Abstract*:* Hunters and research workers took 2,267 deer from the 5,000-acre Hopland Field Station from 1951 through 1974. About half of the deer were bucks taken by hunters and the remainder were antlerless deer shot or trapped for various scientific studies. Compared with this harvest of 12 deer per square mile of range per year, the average hunting kill for Mendocino County during the same period was only two deer per square mile per year. The heavier removal from the Hopland Field Station had no discernable effect on deer numbers, but fawn production and survival on the station were higher than elsewhere in the county. These records show that California deer populations can produce many more deer than are currently being taken with bucks-only hunting and very limited antlerless hunting.

5034. Connolly, Guy E., Robert M. Timm, and Donald T. Torell. 1975. **An automatic nursing device for fawns.** Wildl. Soc. Bull. 3(2):81-82.
Abstract: Wildlife workers often raise deer fawns in captivity for research or exhibition. Labor required to raise fawns by conventional bottle feeding can be reduced by using an automatic nursing device. Fawns broken to bottle feeding take to the nurser readily. This paper describes the nursing apparatus and its use.

5035. Connolly, Guy E., Michael E. Fry, and Janet Fammatre. 1976. **Prey remains at a golden eagle, *Aquila chrysaetos*, nest near Hopland, California.** Calif. Fish and Game 62(1):85-86.
Abstract: Prey remains were gathered from a golden eagle (*Aquila chrysaetos*) nestsite near Hopland following the 1974 nesting season. Materials used by the eagles in construction and lining of the nest are listed. The eagle prey remains consisted mostly of black-tailed deer (*Odocoileus hemionus columbianus*) fawns, gray squirrels (*Sciurus griseus*), and jackrabbits (*Lepus californicus*). Other less abundant prey items included small lambs of domestic sheep (*Ovis aries*), ground squirrels (*Citellus beecheyi*), crows (*Corvus brachyrhynchos*), and a brush rabbit (*Sylvilagus bachmani*).


Guy E. Connolly

A captive coyote selects a lamb to attack in observations of predation behavior, 1975

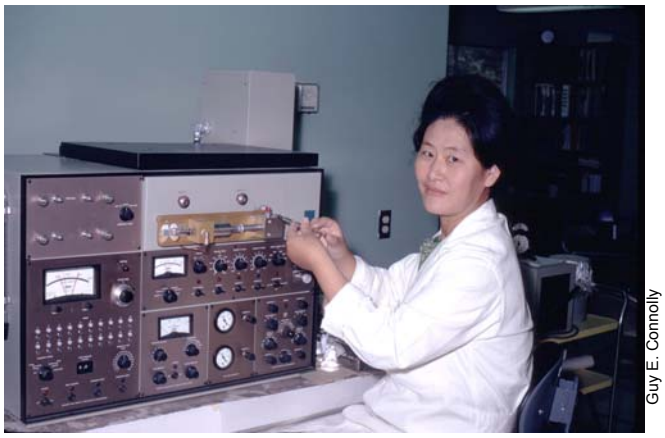
5036. Connolly, Guy E., Robert M. Timm, Walter E. Howard, and William M. Longhurst. 1976. **Sheep killing behavior of captive coyotes.** J. Wildl. Manage. 40(3):400-407.
Abstract: One to four pen-reared coyotes (*Canis latrans*) and one to six sheep were released in 38 tests within a 1,600-m^2 pen and their interactions were observed from a blind. One or more sheep were

killed in 20 tests. Latency to attack averaged 47 minutes in 21 tests. Eight of 11 coyotes individually killed 16 32-kg lambs. The coyotes attaching sheep most frequently were 2-year-old males and females paired with these males. Yearling males attacked less frequently, and unpaired females did not attack. Six of seven kills by male-female coyote pairs were made primarily by the male. Each coyote that killed sheep clamped its teeth in or near the larynx region of the sheep and held on until the sheep succumbed. This technique left characteristic tooth marks and hemorrhaging. The sheep appeared to die primarily of suffocation. Killing time averaged 13 minutes in 20 tests. Food-deprived coyotes fed on the kills for an average of 25 minutes and consumed an average of 2.0 kg/kill. The body parts most frequently eaten from kills were digestive organs and muscle from the hind leg, neck, shoulder, and head. Three of four coyotes fed before tests killed sheep but did not feed on the kills. Defensive behavior by the sheep appeared to deter the coyote attack in 12 tests.

5037. Connolly, Guy E. 1977. **The value of population dynamics models in coyote management.** Trans. West. Assoc. State Game and Fish Comm. 57:93-103.
Abstract: Existing coyote population dynamics models are overly simplistic and they exceed the bounds of existing data. Nevertheless the models offer seemingly reasonable estimates of the ability of coyote populations to withstand predator control. Present models are of limited value to predator control administrators. They provide more information on coyote population dynamics than managers can use, and provide no information on other subjects which must be considered in coyote management decisions. The potential value of models for public education has not been exploited.

5038. Connolly, Guy E. 1978. **Ch. 14. Predator control and coyote populations: a review of simulation models.** Pp. 327-345 *in:* M. Bekoff (ed.), Coyotes: Biology, Behavior, and Management. Academic Press, New York.
Abstract: A simulation model of an animal population mimics or reproduces the numerical behavior of that population over time. Simulation is a systematic way to integrate sets of data on biological processes, such as natality and mortality, which otherwise are available only in fragments. The practical result of such integration is that when one aspect of the biosystem is changed (in the model) the effects of this change on other aspects can be estimated. Simulation models of coyote populations permit estimation of the changes in numbers, pregnancy rates, litter sizes, and other parameters which might result from changes in the intensity of control. The author reviews the history of attempts to control coyotes in the western U.S. over many decades, and he discusses natural limitations on coyote populations. The ability of coyote populations to compensate for control-caused losses is discussed. The structure, assumptions, and design of various coyote population simulation models are discussed, including models that estimate effects on populations of birth suppression and well as increased mortality. The author concludes with a review of the value of simulation models in coyote management, and with a discussion of population suppression vs. selective removal of problem animals.

5039. Connolly, Guy E. 1979. **Deer hunting in Mendocino County, California.** DEER: J. British Deer Soc. 4(8):438-442.
Abstract: Hunters in Mendocino Co., California, participate in the earliest deer season within the lower 48 States, beginning the first Saturday of August each year. The 6- to 7-week hunting season is traditionally held early so that it ends before the rutting season begins in late September. Mendocino Co. contains 3,500 square miles of rugged coastal rangeland and forest, with plant cover ranging from dense redwood and fir forests in coastal areas to oak woods inland. Thick brush (chaparral) covers many of the higher hills and ridges. Deer are abundant and small; the Calif. Dept. of Fish & Game estimates that about 98% of the county is occupied by deer, at an average density of 50 deer / mi^2. The best harvest data comes from the UC Hopland Field Station, where hunter success averages one buck taken in every 12 - 14 hunter days. In Mendocino Co., less than 2 deer / mi^2 are taken annually; the main reason for the low kill is that only 10-15% of deer are legal bucks, and they can easily evade hunters in the dense brush and forests. Information about field-dress carcass weights, antler size, and type of firearms used by hunters is provided. A decline in annual buck kills since 1970 is reported. The author mentions an increasing antihunting and antifirearms sentiment in California, coupled with expansion of the human population into more of the deer range.

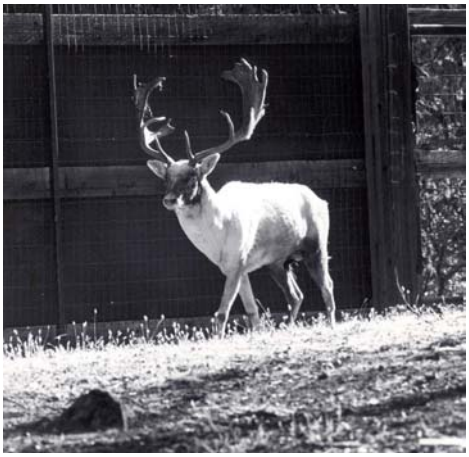

Guy E. Connolly

Lee U. Oh with gas chromatograph used in analysis of volatile fatty acids in rumen samples, June 1972

5040. Connolly, Guy E., Barbara O. Ellison, John W. Fleming, Shu Geng, Richard E. Kepner, William M. Longhurst, John H. Oh, and Gerald F. Russell. 1980. **Deer browsing of Douglas-fir trees in relation to volatile terpene composition and *in vitro* fermentability.** For. Sci. 26(2):179-193.
Abstract: Volatile terpenes in steam-distilled oils from the new growth and year-old needles of browsed and unbrowsed Douglas-fir trees were compared by gas chromatographic analysis. Levels of specific compounds did not differ significantly between browsed and unbrowsed trees in the young growth at bud burst, but differences appeared as the young growth matured. The browsed trees were significantly higher in α-pinene, ß-pinene, *cis*-ocimene, fenchyl alcohol, α-terpineol, and an unidentified sesquiterpene and lower in sabinene, α-terpinene, terpinolene, γ-terpinene, terpinen-4-ol, and α-humulene at one or more sampling times than unbrowsed trees. None of these differences were statistically significant in a smaller sample of trees three years later. Browsed trees had higher levels of microbial promoters and lower levels of inhibitors of rumen fermentation processes than the unbrowsed trees, but they did not differ in *in vitro* fermentability by deer rumen microbes, nor in nitrogen, crude fiber, crude fat, total sugar, sucrose, or moisture content. Significant variations among pairs of trees (sites) were noted for a few terpene components, *in vitro* fermentability, and crude fat. Although terpene concentrations in browsed and unbrowsed trees showed considerable variation, the levels of terpenes that promoted rumen microbial fermentation averaged higher in browsed than unbrowsed trees while those which inhibited fermentation averaged lower. However, overall *in vitro* fermentability of browsed and unbrowsed trees did not differ significantly.

5041. Connolly, Guy E. 1981. **Ch. 8. Assessing populations.** Pp. 287-345 *in:* O. C. Wallmo (ed.), Mule and Black-tailed Deer of North America. Univ. Nebraska Press, Lincoln, NE.
Abstract: To manage deer populations, managers must have information about them. To establish realistic management goals,

and to assess progress toward these goals, management must measure harvests and evaluate their probable effect on populations. This chapter reviews the state of the art in measuring and predicting the dynamics of mule and black-tailed deer populations, and in applying such knowledge to management. The author includes discussion of such topics as age estimation methods (tooth replacement and wear, eye lens weights, counts of annuli in dental cementum), reproduction (ovarian analysis, counts of embryos, fetal sex ratios, effects of nutrition), herd composition counts (principles and assumptions, sample sizes, interpretation of ratios), productivity and rate of increase (definitions of productivity, examples of productivity measures, rates of increase), mortality (fawn vs. older fawn vs. adult mortality, sex-differential mortality of fawns and adults, unbalanced sex ratio at birth, selective hunting of males), and determining harvest (including crippling loss and illegal kill, both during hunting season and out-of-season). He provides detailed discussion of method for estimating deer numbers, including direct counts (sample area counts, aerial counts, strip census, Petersen or Lincoln index), methods based on sign left by deer (track counts, fecal pellet group counts), calculations based on kill statistics and herd composition ratios (number of deer left for each buck killed, change-in-ratio estimates, estimates based on survival or mortality rates), and he compares the various deer census methods. Further discussion is provided on the topics of trend counts, indicators of animal condition, and balancing deer populations with the habitat. A thorough discussion of population analysis and modeling is included, treating such topics as life tables, reconstructions of populations, development of modeling concepts, simulation models of populations, and evaluating the validity of simulation models. Many examples and illustrations are drawn from Hopland Field Station deer studies.



A. H. Murphy

Fallow deer buck was part of a captive herd of these exotic deer maintained at Hopland for ten years, October 1971

5042. Connolly, Guy E. 1981. **Fallow deer in Mendocino County, California.** DEER: J. British Deer Soc. 5(4):175-181.
Abstract: Several small populations of fallow deer (*Dama dama)* exist in California. The ecology of these introduced deer has been studied by various graduate students and wildlife biologists, but few of the results have been published. This paper presents general observations on a small, captive herd of fallow deer maintained on the Hopland Field Station from 1965 to 1975, and also documents the existence of unpublished data on other fallow deer populations in California.

5043. Connolly, Guy E. 1981. **Ch. 7. Limiting factors and population regulation.** Pp. 245-285 *in:* O. C. Wallmo (ed.), Mule and Black-tailed Deer of North America. Univ. Nebraska Press, Lincoln, NE.
Abstract: Deer numbers are limited by some combination of biotic and abiotic influences. A deer population at any given time and place reflects the composite effect of all regulating influences, so that it rarely is possible to quantify the effect of any single factor. Nevertheless, wildlife biologists and managers frequently need to judge the relative importance of such factors. In this chapter, the author provides a discussion of habitat and weather as limiting factors to mule deer and black-tailed deer. A thorough treatment of population regulation by hunting includes such topics as harvestable surplus; hunting as compensatory mortality; effects of hunting on deer numbers, fawn production and survival, population turnover and average age, and on herd composition; and the relationship of hunting to other mortality factors. In a section on management of deer harvest, he discusses the annual cycle of harvest management, management objectives, assessment of population and habitat, harvest goals, hunting success, hunting on ranges shared by mule deer and white-tailed deer, doe hunting, and monitoring the harvest. Non-human predation on deer is discussed, including identification of predator kills; predator selection for weak, sick, or crippled deer; and indirect effects of predation. Nineteen case histories of studies on effects of predation on deer are summarized and presented including predation by wolves, mountain lions, coyotes, and bears. Finally, principles for predator control in deer management are enumerated. Throughout the chapter, deer research from the Hopland Field Station is integrated with findings from other studies conducted throughout the range of mule and black-tailed deer.

5044. Connolly, Guy E. 1990. **The livestock protection collar.** Pp. 89-93 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: The Livestock Protection Collar (LPC) is a new method for killing coyotes that prey on sheep and goats. Collars are placed on livestock that are pastured where coyotes are likely to attack. Attacking coyotes usually puncture the collars and are poisoned. This report describes the LPC and its use, as well as the registered active ingredient, sodium fluoroacetate (Compound 1080). Potential hazards of the active ingredient to non-target species and the environment are discussed.

5045. Coolahan, Craig. 1990. **The north coast animal damage control program.** Pp. 16-22 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: The Ukiah District Animal Damage Control (ADC) program of USDA-APHIS is responsible for protecting cooperating north coast counties' livestock resources from predation by various wildlife species. The district encompasses four counties: Humboldt, Del Norte, Trinity, and Mendocino. Four major mammalian livestock predators exist on the north coast: coyotes, mountain lions, black bears, and dogs. Basic information is provided on how the Ukiah district program deals with various problems caused by these predators, the magnitude of these problems, and current trends in predator damage and take.

5046. Corbett, Christopher W. 1985. **Effects of late-summer sprinkler irrigation on the dynamics of free-living populations of *Microtus californicus*, the California vole.** Ph.D. Dissertation, Univ. Calif. Davis. 160 pp.
Abstract: Populations of the California vole on a northern California rangeland were studied for 26 months using both capture-mark-recapture live-trapping and drift-fence pit trapping programs. During two consecutive summers, two populations were alternately exposed to sprinkler irrigation carried out from August 1st until initiation of the fall rainy season in October (summer rain is atypical in this Mediterranean climate). The two populations were separated by vole-proof fence which served to inhibit movement between the two

sites. It was thought that alleviation of the stressful summer conditions and reduction of soil temperatures by irrigation would result in demographic changes in these vole populations that would persist for a considerable time after the irrigation ceased. Female reproductive activity was stimulated in the irrigated populations, but this did not result in increased recruitment or abundance. Pit trap capture increased briefly in the fall after irrigation, and this supports the Garsd-Howard observation (1981, 1982) that summer soil temperature and pit trap captures are negative correlated. Unfortunately, irrigation in 1984 promoted decomposition and loss of the thatch (ground cover) and appeared to cause the vole population on one quadrant to go extinct. The validity of the experiment as a test of the importance of summer conditions was compromised by this unnatural alteration of the habitat. The populations appeared to fairly closely track their environment. Most negative trends in survival, reproduction, and abundance coincided with poor weather or poor ground cover while most positive trends were closely aligned with favorable weather and improvements in ground cover.

5047. Cornett, D. C., W. M. Longhurst, R. E. Hafenfeld, T. P. Hemker, and W. A. Williams. 1979. **Evaluation of the potential impact of proposed recreation development on the Mineral King deer herd.** Pp. 474-480 *in:* The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats (G. A. Swanson, tech. coord.), Rocky Mt. For. Range Exp. Stn., For. Serv., USDA, Fort Collins, CO, Gen. Tech. Rep. RM-65.
Abstract: A study in 1976-77 of the Mineral King deer herd in California assessed herd ecology and impacts of proposed recreation development, and formulated mitigation plans. Field studies defined range conditions and utilization, herd size and composition, migratory movements, and disturbance by existing recreation. Range improvements, better herd management, and modified development were principal mitigations recommended.

5048. Corrigan, Robert M., and Robert M. Timm. 1993. **Controlling rodents in commercial poultry facilities.** ADC-3, Cooperative Extension Service, Purdue University, West Lafayette, IN. 16 pp.
Abstract: This extension bulletin provides information on methods of preventing or solving damage caused by house mice (*Mus musculus*) and Norway rats (*Rattus norvegicus*) in commercial poultry facilities. Damage, including their potential role in spreading poultry disease, is described. Rodent biology and behavior is briefly discussed, as well as methods of inspecting premises for evidence of infestation. Control methods recommended include sanitation, rodent-proof construction, and population reduction using traps and/or rodenticide baits. The publication includes a "how-to" guide to conduct safe and effective rodenticide baiting in various types of poultry facilities.

5049. Cummings, Maynard W., Marston H. Kimball, and William M. Longhurst. 1963. **Deer-resistant plants for ornamental use.** Leaflet 167, Calif. Agric. Exper. Sta. and Extens. Serv., Div. Agric., Univ. Calif.
Abstract: Deer, like all animals, have certain food preferences and dislikes. The use of deer-resistant plants to minimize damage from browsing has a number of advantages for the home gardener. Resistance to deer is related to the availability of other food: if there is an adequate supply of natural browse in the deer's usual feeding ground, ornamental plantings may be largely untouched. However, if there is an extreme shortage of food, few if any plant species are totally resistant to deer. Palatability of some plants varies with stage or growth or with plant age and season of the year. This general guide lists alphabetically plants with some degree of deer resistance, useful in California landscapes. Particularly-resistant plant species are noted.

5050. Dasmann, Raymond F., Richard L. Hubbard, William M. Longhurst, George I. Ramstead, Joseph H. Harn, and Emmett Calvert. 1967. **Deer attractants – an approach to the deer damage problem.** J. Forestry 65(8):564-566.
Abstract: Attractants which might be used to lure deer away from conifer reproduction include: 1) molasses, other sweeteners, minerals, or trace elements which, when sprayed on plants, increase the plant's palatability to deer; 2) plants which are naturally highly preferred by deer; and 3) supplements such as hay, pellets, or trees and large brush plants which are felled so that deer can feed on foliage they otherwise could not reach.

5051. DeMartini, James C., and Guy E. Connolly. 1975. **Testicular atrophy in Columbian black-tailed deer in California.** J. Wildl. Dis. 11:101-106.
***Abstract*:** During an 18-year period, 4.1% (34/831) of male deer (*Odocoileus hemionus columbianus*) killed on the Hopland Field Station during autumn hunting season had velvet-covered, often misshapen antlers, and at least two deer had testicular atrophy (gonads from most deer were not available for examination). Testes from six similarly affected deer and several normal deer were compared histologically. Lesions ranged from hypocellularity of the seminiferous tubules and relative hyperplasia or degeneration of interstitial cells to complete connective tissue replacements of the testicular parenchyma. Chronic vascular change were present in several testes. The etiology and pathogenesis of the lesions was not determined.


Guy E. Connolly

UC Davis graduate student Bob Timm examines coyote removed from field station, March 1976

5052. Dow, Ronald J. 1975. **Analysis of four populations of free-ranging coyotes in California.** M.S. Thesis, Univ. Calif. Davis. 54 pp.
Abstract: The purpose of this study was to determine the sex and age-class compositions of free-ranging coyote populations from four geographical regions within California: the Coast Range, the Sacramento Valley, the Sierra Nevada foothills, and the Sierra Nevada. The three major objectives were: 1) to determine the most accurate method for coyote age assessment, 2) to set up age frequency and sex composition tables for each population, and 3) to determine differences which may occur among the four populations by comparing the age frequency data of each statistically. Comparisons showed that age frequency data from the alpine population were significantly different than the other three groups. This was due to the low frequency of individuals in the first two age classes. The sample was taken too early in the summer for the pup population to be representative in the control take. It appears that yearling emigration from this population is high. Age frequency data

from the foothill population exhibited significance when compared with information from the coast population and approached significance when compared with the valley population. In the foothill population 85% of the coyotes were three years old or less, whereas only 77% of the valley and 68% of the coast populations were comprised of individuals within the same age groups. A comparison of the age structure of the sexes of each population revealed no significant differences. The sex ratio was within ±4% of being 50:50 in every population. Differences were evident when spring and fall sex ratios were compared. Males were predominant in the fall population (57%), while females appeared in higher numbers in the spring (53%). Juvenile males were predominant over females in both spring and fall samples. Adult females comprised 40% of the entire spring take.

5053. Elliott III, Henry W. 1973. **A field survey of the exotic axis deer at Point Reyes National Seashore.** M.S. Thesis, Univ. Calif. Berkeley. 40 pp.
Abstract: Approximately 400 axis deer (*Axis axis axis*) inhabited Point Reyes peninsula in October 1973. A 22% estimated yearly increase of the female population will result in continued increase and expansion of axis deer throughout the pastures grazed by cattle. Competition lowers the carrying capacity for cattle but is probably not affecting the axis deer.

5054. Erickson, Mandy. 2001. **Suburbia aside, black-tailed deer are in decline.** Calif. Agric. 55(6):11-12.
Abstract: This brief article notes the apparent decline in black-tailed deer resident on the Hopland R & E Center over the past several decades. Researchers during the 1960s estimated deer numbers at about 600 adult animals, but population estimates from the early 1990s indicated perhaps only half that number. California Fish & Game records from Mendocino and Sonoma counties support this decline, which was first noted in about 1969. UC Berkeley researcher Dale McCullough notes the behavior of deer in California has changed dramatically, enabling them to live in suburban areas such as the Bay Area where they damage landscaping, cause traffic hazards, and can attract predators such as mountain lions. Speculation on the causes for this deer decline is discussed, including such factors as climatic change, predation and hunting pressures, historic overpopulation, and changing land use patterns.

5055. Ernest, Holly. 2000. **DNA analysis for mountain lion conservation.** Outdoor Calif. 61(3):16-19.
Abstract: The article describes use of DNA technologies to study California's mountain lion population. Among findings are the ability to identify individual mountain lions responsible for killing livestock or threatened wild prey. DNA extracted from saliva present on carcasses of sheep killed at Hopland allowed the identification of the specific mountain lion responsible, which was subsequently killed on a depredation permit nearby.

5056. Ernest, Holly B., and Walter M. Boyce. 2000. **DNA identification of mountain lions involved in livestock predation and public safety incidents and investigations.** Pp. 290-294 *in:* Proc. 19th Vertebr. Pest Conf. (T. P. Salmon and A. C. Crabb, eds.), San Diego, CA, Mar. 6-9.
Abstract: Using three case studies, we demonstrate the utility of techniques to analyze DNA from trace samples collected at sites of livestock predation and public safety incidents. Genetic analysis was used to determine species, individual identity, and relatedness between individuals. We documented the presence and individual identities of a mountain lion (*Puma concolor*) and a bobcat (*Lynx rufus*) from swab samples collected from bite wounds in domestic sheep that had been killed at the UC Hopland Res. & Ext. Center, Mendocino County, CA. Four lions and two bobcats in Redwood National Park were individually identified and tested for relatedness using DNA from scats and captured animals. Another lion was genetically typed and matched at a public safety incident through blood spots left near a barn in one location in the San Joaquin Valley and muscle sample collected from a lion captured 10 miles distant 1 week later. We applied statistical techniques developed for human forensic DNA analysis and a DNA database that we have compiled for California mountain lions.

5057. Fagre, Daniel B., and Walter E. Howard. 1980. **Factors affecting killing behavior in coyotes (Abstract).** P. 21 *in:* Abstracts, 61st Ann. Mtng, Pacific Div., Am. Assoc. for the Advance. Science, and West. Sect., Ecol. Soc. of Amer., Jun. 22-27.
Abstract: Several aspects of killing behavior in coyotes are illustrated in a color movie. This movie presents results from studies evaluating the relative importance of prior killing experience, encounters with aversive prey, the presence of alternative prey, and multiple prey in influencing prey choice, latency to attack, avoidance behavior, and consumption. Although distinct prey preferences and some prey aversions could be readily conditioned in individual coyotes, this was partially mitigated by the number of prey presented. Most dramatically, when single repellent-treated prey were presented to conditioned coyotes, either no attack or complete avoidance occurred. However, when three or more repellent prey were released in the test area, vigorous killing of all prey was evident despite the incapacitating effects of the repellent to the coyote. In addition, results from tests with visual and olfactory mimics of the repellent prey indicate that coyotes rely on vision before olfaction in selecting prey for attack.

5058. Fagre, Daniel B., Ann Casler-Fagre, and Walter E. Howard. 1980. **Progress in coyote attractants research.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," North Bend, OR, Aug. 19-20. 5 pp. + figs.
Abstract: Progress in evaluating candidate coyote attractants during the past year is reported, in an effort to enhance methods of coyote control. Behavioral responses were measured using captive coyotes at Hopland. Trimethylamine, which has previously been isolated from anal sac compounds in coyotes and dogs, was identified as a component of the neutrals fraction of coyote urine. It is also a component of decaying carcasses. Coyotes exhibited 80% as much interest to the related compound trimethylammonium valerate (TMAV) alone as to the complex urine acids fraction. We infer that trimethylamine may be one of the key attractants to which coyotes respond when they investigate urine marks left by conspecifics. Investigation of a very effective commercial coyote lure, Carman's Distant Call Lure, suggests that sulfides play an important role in eliciting coyote responses. Sulfides, which are also found in canid urine, were mixed with TMAV and were found to enhance attractancy. Lick-chewing responses of coyotes were enhanced when odors were presented on objects coyotes could easily bite and tug (absorbed onto a piece of sheepskin). Even greater interest and lick-chew response was seen when a solution of sucrose, glycerol, and water was applied to the odorized sheepskin. Monosodium glutamate, salt, and proline all detracted from attractancy when added to scented sheepskin.

5059. Fagre, Daniel B., Barbara A. Butler, Walter E. Howard, and Roy Teranishi. 1981. **Behavioral responses of coyotes to selected odors and tastes.** Pp. 966-983 *in:* Proc. World Furbearer Conf., Vol. 2 (J. A. Chapman and D. Pursley, eds.), Frostburg, MD, Aug. 3-11, 1980. Univ. Maryland.
Abstract: The relative interest levels of captive coyotes (*Canis latrans*) for numerous odors and for chemical fractions of coyote urine were determined systematically by using a standardized format. The responses by the coyotes were consistent and fairly predictable and did not attenuate through repeated exposure to an attractive odor,

or vary by geographic source of the coyote urine. Acids and neutrals fractions of urine received 2.5 times more interest than whole urine and the time spent at them increased when the fractions were concentrated. Male coyotes differentiated between estrous and nonestrous female urine, and its fractions. Trimethylamine, found in coyote urine, was highly attractive. Trimethylammonium valerate with ethylbutylsulfide added was the third most attractive substance tested. The addition of various sulfides that are found in commercial trap lures improved the attractability of more odors. The licking-chewing response elicited by some odors presented on a piece of sheepskin on a post increased dramatically if sucrose was added, but was not enhanced by taste additives such as proline, monosodium glutamate, and flavor potentiators.

Robert M. Timm

Captive coyote feeding on lamb it has killed in an experimental observation of predation behavior, January 1976

5060. Fagre, Daniel B., Walter E. Howard, and Rex E. Marsh. 1981. **Factors affecting coyote killing behavior: an artificial model-mimic prey system.** Pp. 950-965 *in:* Proc. World Furbearer Conf., Vol., 2 (J. A. Chapman and D. Pursley, eds.), Frostburg, MD, Aug. 3-11, 1980. Univ. Maryland.
Abstract: We tested the hypothesis that when all chickens (or sheep) cannot be treated with a coyote repellent, a model-mimic system might be created with the untreated animals being the mimics. This study used brown chickens treated with oleoresin of capsicum as the models. The repellent stopped most lethal attacks on the treated models, but the basic goal of protecting the untreated mimics was not realized. The coyotes whose first exposure to live chickens was with treated models subsequently investigated and then killed untreated mimics. Even though averted coyotes preyed first on alternate prey (untreated white chickens), and changes in killing behavior toward the model chicken were evident, the strong predatory drives of the coyotes prevented any permanent avoidance patterns being established.

5061. Fagre, Daniel B., Douglas A. Barnum, A. Casler-Fagre, and Walter E. Howard. 1981. **Development of coyote attractants: 1980-1981 progress report.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Twin Falls, ID, Aug. 11-12. 1 p.
Abstract: Some 362 tests of 26 different candidate attractant odors, utilizing captive coyotes at Hopland, were completed within the last year. Progressive lengthening of the carbon chain of the trimethylamine (TMA) attractants indicated that trimethylammonium decanoate (TMAD) was significantly more attractive than any other TMA compound. Licking and chewing behaviors toward this compound occurred more often, as well. Additives to TMAD, such as methyl ketones, putrescine, and cadaverine, evoked more coyote interest as well as increasing lick-chew response. Sulfides, particularly methylbutyl sulfide, increased the attractancy of TMAD to coyotes. Of all compounds and mixtures tests, two complex organic substances, Carman's Distance Call Lure and sheep liver extract, were the most attractive. A number of candidate synthetic attractants are sometimes as effective as the best commercially available organic coyote lures.

5062. Fagre, Daniel B., Walter E. Howard, and Rex E. Marsh. 1981. **Conditioned avoidance for a repellent prey and its mimics.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Twin Falls, ID, Aug. 11-12. 1 p.
Abstract: We tested the possibility that avoidance behavior could be conditioned in coyotes as a result of attacking repellent-treated models. Theoretically, this established avoidance could preclude coyote attacks on similar-appearing by untreated prey (mimics). Using brown chickens coated with oleoresin of capsicum (a repellent) as models and untreated brown chickens as mimics, avoidance of mimics was evident 48 hours after captive coyotes were repelled by the models, but the simultaneous presence of alternative prey was necessary for the avoidance to last longer than 15 minutes. Even with alternative prey present, this avoidance of mimics was short-lived. Coyotes quickly began re-investigating and killing mimics after only a few (1-3) exposures to these prey. Eventually, 7 of 10 coyotes also adapted to the presence of the repellent and began successfully killing models. Thus, no ratio of models to mimics consistently protected mimics from coyote attack, although coyotes continued to kill mimics with apparent anxiety (as if expecting the repellent to be present). Surplus killing of these treated and untreated chickens also occurred frequently with the more aggressive coyotes.

5063. Fagre, Daniel B. 1981. **Inhibition of predatory attacks by captive coyotes: conditioned avoidance for a repellent prey and its mimics.** Ph.D. Dissertation, Univ. Calif. Davis. 224 pp.
Abstract: Conditioned avoidance by predators for prey with chemical antipredator defenses occurs naturally, and behavioral modification of this sort potentially provides an attractive alternative to lethal control of sheep-depredating coyotes (*Canis latrans*). Because an artificial defense, such as a repellent, cannot reasonably be applied to every sheep in the field, the untreated sheep become mimics of the treated sheep (models). Thus, a truly successful repellent must condition avoidance for mimics as well. One of the best potential repellents, oleoresin of capsicum, was evaluated for its abilities to inhibit captive coyotes' attacks on, and condition avoidance for, a specific prey (treated brown chickens) and for its mimics (untreated brown chickens). Treated brown chickens (models) were completely protected from lethal coyote attacks and distinct avoidance of models by 3 of 4 coyotes occurred during their second exposure. No mimics were killed when an alternative choice, a white chicken, was present. However, the initial avoidance responses were soon lost. Only 3 out of 10 coyotes failed to kill models eventually and no coyote consistently avoided mimics. The mimicry concept is unlikely to be effective in deterring coyote predation on sheep. Even if every sheep were repellent treated, those repellents developed to date probably would not reduce predation sufficiently to justify the expense of application. Other difficulties in consistently reducing coyote predation on sheep are discussed.

5064. Fagre, Daniel B., Douglas A. Barnum, and Walter E. Howard. 1982. **Increasing captive coyote responses to W-U lures.** Pp. 7-8 *in:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Waco, TX, Aug. 10-11.
Abstract: Responses of captive coyotes at Hopland to a variety of

candidate attractant compounds are summarized. Sulfides have markedly increased the response to trimethylammonium decanoate (TMAD), and have been combined to form the lure designated "W-U 127." While addition of methyl ketones to TMAD resulted in a lure than evoked 11% more coyote responses than W-U 127, the addition of methyl ketones to W-U 127 resulted in a combination that was not significantly more attractive than TMAD alone. It was concluded that combining too many attractant constituents (both sulfides and ketones) with TMAD into a single mixture had a negative effect on coyote response. To correct the problem of TMAD being too concentrated to be effective in field use, we investigated a lard:beeswax:glycerol (LBG) mixture, as well as mixtures utilizing paste or commercial lard as diluents. A lard:W-U 127 mixture (0.1 ml/lb) was not significantly different in attractiveness than Carman's Distant Call Lure. The lard appeared to enhance the lick-bite response of coyotes to W-U lures, eliciting these behaviors 100% of the time for W-U 127. This could be valuable in further development of a bait deliver system as well as for use as a lure on M-44 devices. Because the LBG and lard alone both were attractive to non-target species, we formulated a glycerol:gum carrier, which in pen tests elicited no interest from non-targets. Field tests of this carrier using W-U 127 as the attractant are needed. TMAD shows consistent seasonal variation in coyote attractancy, with high response in Dec. - Feb. and low response in Apr. - May.

5065. Fagre, Daniel B., Walter E. Howard, and Roy Teranishi. 1982. **Development of coyote attractants for reduction of livestock losses.** Pp. 319-326 *in:* Proc. Wildl.-Livest. Relationships, Symp. 10 (J. M. Peek, and P. D. Dalke, eds.), Coeur d'Alene, ID, Apr. 20-22, 1981. Univ. Idaho.
Abstract: Odors play a major role in coyote behavior and biology, and humans often depend upon the attractiveness of odoriferous substances to control coyote depredations. Despite these considerations, the specific chemical basis for the attractiveness of coyote urine is not well understood. Quantifying the behavioral responses of coyotes to chemical fractions of urine and systematically bioassaying components of these fractions led to the development of trimethylammonium valerate (TMAV) as an effective odor attractant for coyotes. This has been improved upon with the addition of ethylbutylsulfide to TMAV. These two compounds elicit more interest than hundreds of other substances tested, all of which are considerably more complex chemically.


Jack Kelly Clark

A captive coyote investigates a candidate lure applied to an experimental bait post, June 1983

5066. Fagre, Daniel B., Walter E. Howard, Douglas A. Barnum, Roy Teranishi, Thomas H. Schultz, and Donald J. Stern. 1983. **Criteria for the development of coyote lures.** Pp. 265-277 *in:* D. E. Kaukeinen (ed.), Vertebrate Pest Control and Management Materials. STP 817, Am. Soc. for Testing and Materials, Philadelphia, PA.
Abstract: The behavioral responses that coyote lures must elicit to attract coyotes to control devices, and the chemical characteristics of lures that are required for practical field use are described. These criteria are being applied to the development of a new lure, designated the W-U lure. The first phase involves isolation, identification, and bioassay of key attractants found in coyote urine and anal sacs. Some of these chemicals have been formulated into the W-U lure, which elicits a greater degree of response from captive coyotes than any other synthetic lure and all but one commercial lure tested to date. The second phase of lure development entails standardized evaluations of the W-U lure by comparing it with other attractants in the field using a modified scent station survey. Distributing the W-U lure to field personnel responsible for controlling coyote damage also provides invaluable feedback, but standardized comparisons cannot be made. Preliminary results from both sources of field evaluation indicate that the W-U lure can be contribute to improving coyote management.

5067. Fagre, Daniel B., and Steven M. Ebbert. 1988. **Development and testing of the coyote lure operative device.** Pp. 235-240 *in:* Proc. 13th Vertebr. Pest Conf. (A. C. Crabb and R. E. Marsh, eds.), Monterey, CA, Mar. 1-3.
Abstract: A new device for orally delivering substances to coyotes (*Canis latrans*) has been under development for approximately 10 years. The development of the coyote lure operative device (CLOD) is described along with some recent field evaluations of the CLOD system. In general, the results of these field tests indicate that the CLOD shows potential and merits further development.

5068. Fisher, Daryl D., Robert M. Timm, Richard M. Poché, and Scott E. Hygnstrom. 1991. **Laboratory study on bromadiolone: effectiveness on prairie dogs and secondary hazards to domestic ferrets.** Pp. 70-72 *in:* Proc. 10th Gt. Plains Wildl. Damage Control Wkshp. (S. E. Hygnstrom, R. M. Case, and R. J. Johnson, eds.), Lincoln, NE, Apr. 15-18.
Abstract: Hulled whole oats treated with 0.00228% bromadiolone were found to be an effective prairie dog toxicant in the laboratory. All prairie dogs offered 15 g of bait daily for 3 days died of anticoagulant poisoning. Testing of secondary toxicity showed no mortality or apparent sublethal effects to domestic ferrets fed bromadiolone-killed prairie dogs over 6 days. While our testing regime cannot demonstrate efficacy or safety in field situations, it would indicate that this compound is worthy of further study.

5069. Fry, Michael E., and Charles E. Vaughn. 1977. **Acorn selection by band-tailed pigeons.** Calif. Fish and Game 63(1):59-60.
Abstract: In 1975, a heavy crop of blue oak (*Quercus douglasii*) acorns attracted a large population of migratory band-tailed pigeons (*Columba fasciata*) to the Hopland Field Station. Data on the selectivity of feeding by pigeons was obtained by collecting birds during the period October 4 through October 19. Sampled birds fed exclusively on sound blue oak acorns and acorns selected by pigeons were significantly smaller than randomly collected acorns.

5070. Garsd, Armando. 1979. **The statistical analysis of fluctuations and cycles in microtine populations.** Ph.D. Dissertation, Univ. Calif. Davis. 114 pp.
Abstract: This dissertation investigates the ecological and statistical interrelations of a number of fluctuating microtine (*Microtus californicus*) populations. Eight records from the literature, two from enclosures, one from a control area at the UC Hopland Field Station, and two from a laboratory experiment are studied and compared. The existence and consequences of periodic and pseudoperiodic

performances are analyzed by using relatively simple models. Limitations of statistical procedures are discussed. Results from the literature concerning the genetic hypothesis are re-examined. Methodological difficulties in the assessment of causation and the effectiveness of forecasting are discussed in the specific context of microtine fluctuations. The relevance of statistical analysis of fluctuating populations is discussed in terms of its connections with other topics in applied and theoretical ecology. Six sets of statistical procedures are introduced in order to explain variability in the Hopland series from an ecosystem perspective. This led to a tentative 90-95% reduction in variability. A model is fit to bimonthly data from the Hopland Station. The effect of the fluctuating character of abiotic and biotic factors at the Hopland ecosystems on this data is evaluated. Three new concepts, unrealized-, image-, and antiecosystems are introduced as useful in understanding and describing fluctuations. The genetic hypothesis is reformulated to involve the ecosystem.

5071. Garsd, Armando, and Walter E. Howard. 1981. **A 19-year study of microtine population fluctuations using time-series analysis.** Ecology 62(4):930-937.
Abstract: This report involved time-series statistical analysis (including concurrent physical and community variables) of the population dynamics of 4,737 voles (*Microtus californicus*) trapped over 19 years while emigrating from two study enclosures on a Northern California grassland. Population fluctuations of voles, as documented in the literature as well as in this study, generally cannot be described by periodic or regularly cyclic equations, but rather are either random or occasionally pseudoperiodic where auto regressive correlation explains irregular cycles on the basis of the population's previous demographic history. For these two California vole populations, an auto regressive component accounted for approximately a third of the total variability in the population, while random extrinsic environmental variation explained almost all of the remaining variation. Weather played a key determinant role, influencing microtine populations both directly, and indirectly through an effect on vegetation. The distinction between periodic, pseudoperiodic, and random fluctuations in vole populations, and indeed in wildlife populations in general, cannot be dismissed as merely a question of semantics, because each entails a specific ecologic interpretation. The demographic characteristics of microtine rodents, although fluctuating more dramatically, were similar to those of other rodents.

5072. Garsd, Armando, and Walter E. Howard. 1982. **Microtine population fluctuations: an ecosystem approach based on time-series analysis.** J. Anim. Ecol. 51(4):225-234.
Abstract: This time-series analysis describes the bimonthly population dynamics of 5,308 voles (*Microtus californicus*) trapped in pit traps set continuously for over 21 years, while emigrating from two study enclosures on a Northern California grassland. A simple model is introduced to quantify seasonality in microtines and to relate seasonal population fluctuations to concurrent physical community variables. Seasonal variation represented 33 to 46% of the observed total variability. Weather played a determining role in nonseasonal microtine population fluctuations, both directly and indirectly, through an effect on vegetation. Correlation between indicators of solar activity and nonseasonal microtine fluctuations may represent either a direct effect of these cosmic variables or a synchronous environmental effect of the Eltonian type.

5073. Gilson, Arlette, and Terrell P. Salmon. 1990. **Ground squirrel burrow destruction: control implications.** Pp. 97-98 *in:* Proc. 14th Vertebr. Pest Conf. (L. R. Davis and R. E. Marsh, eds.), Sacramento, CA, Mar. 6-8.
Abstract: Rapid reinvasion of low-density sites by dispersing ground squirrels often results in short-term benefits from otherwise effective population control methods. Existing vacant burrow systems appear to play an important role in facilitating the local population recovery. The potential of destroying the ground squirrel burrow entrances to reduce site reinvasion, following population removal, was tested. Under the conditions of the tests, deep ripping resulted in >85% reduction in burrow reinvasion by California and Belding ground squirrels. Studies are still in progress to evaluate the consistency of the results and include long-term effects and cost information. The inclusion of this technique into the management of crops rather than the management of one pest species alone is discussed.

5074. Giusti, Gregory A., and Robert H. Schmidt. 1988. **Human, bears, and redwoods: a need for applied environmentalism.** Trans. West. Sect. Wildl. Soc. 24:135-143.
Abstract: Controversy exists in Humboldt and Del Norte Counties in northern California about the strategies and techniques used to reduce black bear (*Ursus americanus*) damage to coast redwoods (*Sequoia sempervirens*). In this paper we review what is known about the biology of bears living in coast redwood habitat as well as redwood forest management techniques. We propose a new strategy for dealing with bear damage problems to redwoods based on current knowledge, new research, and an awareness and appreciation for both wildlife values of bears and legitimate commercial management and use of redwood timber.

5075. Giusti, Gregory A., Robert M. Timm, and Robert H. Schmidt (Editors). 1990. **Proceedings, Predator Management in North Coastal California.** Ukiah and Hopland, CA, Mar. 10-11. Publ. 101. Hopland Field Station, Univ. Calif. 95 pp.
Abstract: This Proceedings includes 15 papers dealing with damage assessment, predator biology, and predation-livestock management, with particular reference to coyote, mountain lion, and bear conflicts with livestock and human enterprises in north coastal California over the past two decades.

5076. Giusti, Gregory A., Robert H. Schmidt, Robert M. Timm, John E. Borrecco, and Thomas P. Sullivan. 1992. **Ch. 14. The lagomorphs: rabbits, hares, and pika.** Pp. 289-307 *in:* H. C. Black (tech. ed.), Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests. Gen. Tech. Rep. PNW-GTR-287. USDA For. Serv., Pac. Northwest Res. Sta.
Abstract: Rabbits, hares and pika have all been implicated in causing damage to trees in the Pacific Northwest. Damage is generally to seedlings, limbs, and saplings smaller than 2.5 inches in diameter, with damage involving either clipping of the stem or bark removal as the lagomorphs are feeding. Damage prevention methods include synthetic or biological repellents, exclusion (individual seedling protectors or fencing), or lethal control methods such as poisoning or shooting. Silvicultural methods useful in reducing lagomorph damage include vegetation management, thinning, fertilization, and selection of browsing-resistant seedling sizes.


Robert J. Keiffer

Pair of western bluebirds on nest box, Lambing Pasture, 1989

5077. Giusti, Gregory A., and W. Paul Gorenzel. 1993. **4-H Bluebird Nestbox Project.** UC Cooperative Extension Publ., Ukiah, CA. 12 pp.
Abstract: This publication provides 4-H members and other youth with basic information on building nest boxes to attract western bluebirds. Bluebird biology is briefly summarized. Design and construction details for making nest boxes from wood are given. Nest box maintenance is discussed. Appendices include a glossary of terms and a list of other California species that use nest cavities.

5078. Giusti, Gregory A., Thomas R. Scott, Barry Garrison, and K. Shaffer. 1996. **Ch. 4. Oak woodland wildlife ecology, native plants and habitat relationships.** Pp. 34-50 *in:* R. B. Standiford and P. J. Tinnin (tech. coords.), Guidelines for Managing California's Hardwood Rangelands. UC DANR Publ. 3368, Integrated Hardwood Range Management Program, Univ. Calif.
Abstract: Wildlife habitat relationships, habitat scale concepts, and habitat structure are defined and explained in this chapter, for the purpose of assisting landowners to properly manage oak woodlands as important wildlife habitat. Wildlife habitat use is discussed. A section on sensitive plants explains management techniques needed to conserve these resources. Worksheets, along with definitions of terms, are provided for landowners to evaluate their own management practices in relation to these recommendations.

5079. Gorenzel, W. Paul, Sonke A. Mastrup, and E. Lee Fitzhugh. 1991. **Settling and other physical characteristics of brushpiles of different sizes and construction.** Trans. West. Sect. Wildl. Soc. 27: 1-10.
Abstract: We examined oak brushpiles typically recommended for quail management. We measured height, interior space, and settling rates; derived loft values (the percent of interior space relative to height); and subjectively rated interior space, leaf retention on brushpile branches, and grass and lichen growth in brushpiles. We obtained data from 12 new, modified-teepee design brushpiles 3.0 to 3.7 m diameter in Mendocino County from October 1987 through October 1990 (1,106 days) and from 36 new, horizontal-design brushpiles (12 each with diameters of 1.5, 3.0, and 4.6 m) in Yuba County from September 1988 through May 1990 (596 days). Declines in brushpile heights ranged from 50% to 53% for both designs, but the modified teepee brushpiles retained height, interior space, and loft longer than the horizontal design brushpiles. Larger brushpiles retained leaves on their branches longer and had less grass growth inside them than smaller brushpiles. Subjective ratings of interior space quality indicated adequate openings for bird access and movement still existed within the modified teepee brushpiles after 1,106 days and within the horizontal design brushpiles after 596 days. We used regression equations to describe the changes in the above brushpile characteristics. We speculate that leaves on brushpile branches are a favorable component of cover for birds; that dense grass within brushpiles deters bird use; and that a size-age-utility relationship exists: the larger a brushpile is in height and basal area when built, the longer it will remain useful for birds.

5080. Gorenzel, W. Paul, Robert H. Schmidt, and Gregory A. Giusti. 1993. **Want to help wildlife? Start a nest box trail!** Outdoor Calif. 54(1):11-16.
Abstract: This article provides a description of a nest box that can be built to attract western bluebirds. Installation, management, and siting of nest boxes are included. Control of wasps and prevention of nest damage by predators are discussed.

5081. Green, Jeffrey S. 1990. **Reducing predation with guarding animals.** Pp. 62-68 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: A growing number of livestock producers are using guarding animals as part of their program of predation management. Heading the list of animals used are dogs of various Eurasian breeds. The success of a particular dog is related somewhat to breed, but probably most important is how the dog is reared and handled. Other guarding animals used include donkeys and to a significantly lesser extent, llamas, cattle, mules, and goats. The success of a guarding animal is related to a combination of factors, but two important ones are 1) the innate fear wild predators have for a novel stimulus, and 2) the active aggression toward the predator from the guarding animal.

5082. Hackett, Dick. 1990. **Predator problems on California's north coast: economic impacts.** Pp. 23-27 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.) Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: Predators have been a serious problem to north coast livestock producers for many years, particularly to those in the sheep industry. Serious economic hardships have driven many producers out of the sheep business. Many have gone to all-cattle operations, and several have been forced to go out of business completely. Data are provided on livestock killed near Redwood State/National Park during the 1970s, and sheep and lamb numbers in Humboldt Co. from 1950 to 1988.

5083. Halter, A. N., William M. Longhurst, Guy E. Connolly, and F. M. Anderson. 1972. **The practical applications of simulation modeling in wildlife management.** Pp. 308-320 *in:* Proc., West. Assoc. State Game and Fish Comm. and Western Div., American Fisheries Soc., Vol. 52, Portland, OR, Jul. 19.
Abstract: This paper describes a deer herd simulation model created in order to test the effects of hunting on the deer population in Mendocino County, CA. Data from the deer herd at the Hopland Field Station was utilized to build the model. Outputs from this model, using various assumptions and conditions, shows that the current level of hunting provides neither an effective means of deer population control nor maximizes legal buck kill. Population control is desirable and can be achieved only by antlerless hunting. The legal buck kill is maximized when mixed buck and antlerless deer hunting is conducted. Computer simulation models of wildlife populations can be used to investigate a wide range of management alternatives. Game managers can use such models to evaluate proposed hunting regulations prior to implementation. Combined with effective public relations, results from computer simulations should be useful in educating the public about basic biological facts and informing them of the consequences of policy formulated from ignorance or advocated by special interest groups.

5084. Hanson, W. C., A. H. Dahl, F. W. Whicker, W. M. Longhurst, V. Flyger, S. P. Davey, and K. R. Greer. 1963. **Thyroidal radioiodine concentrations in North American deer following 1961-1963 nuclear weapons tests.** Health Physics 9:1235-1239.
Abstract: Radioiodine concentrations were measured in deer, elk, caribou and reindeer thyroids collected in Alaska, California, Colorado, Maryland, Washington and Wyoming during the period September 1961 through mid-April 1963. Periods of maximum ^{131}I concentrations in most samples occurred in winter months, about 2-3 months after initial atmospheric tests. Values during the 1961 peak period were slightly greater than during the 1962 peak period but were maintained over a shorter period of time. The ^{131}I concentrations showed a clear response to each series of nuclear tests conducted by France, Russia, and the United States. Maximum response occurred following tests conducted in the atmosphere and the Sedan detonation on 6 July 1963; least response followed underground tests. Thyroid doses received by the various animal groups from ^{131}I during the 1962-1963 nuclear tests varied from

about 20 rad in Colorado deer to 0.8 rad in Alaskan reindeer, compared to 5.1 and 1.2 rad, respectively, in similar samples collected during the 1961-1962 nuclear test series.

5085. Harris, Robert S. 1972. **Fatty acids of deer muscle as influenced by differing feed habit zones.** M.A. Thesis, Sonoma State College. 53 pp.
Abstract: Fatty acid ratios from muscle tissue of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) from three feed habit zones were analyzed. One group of deer came from an oak woodland feed zone in which the deer were eating primarily grass, leaves, and other water-rich forage. Another group of deer came from a higher elevation chaparral area in which the diet consisted of chamise (*Adenostoma fasciculatum*), oak leaves and acorns (*Quercus* spp.), and manzanita (*Arctostaphylos* spp.). The consumption of manzanita is surprising. It is normally avoided because of the presence of phenolic compounds, such as tannic acid, in the leaves. A third group of deer cam from a similar chaparral area that had been previously burned over and had regrown. The diet here consisted of the new shoots of the various chaparral plants and some grass. The burned chaparral feed zone is viewed as intermediate between the native chaparral and the oak woodland feed zone. Fatty acid ratios differed markedly between the native unburned chaparral and the oak woodland feed zone. In the unburned chaparral the unsaturated fatty acids accounted for 54% of the total and the saturated fatty acids were 46%. The oak woodland deer had 43% unsaturated fatty acids and 57% saturated fatty acids. The burned chaparral deer showed an equal division between the unsaturated and saturated fatty acids. The theory is advanced that the tendency of the rumen to carry out biohydrogenation of unsaturated fatty acids is inhibited by the toxic phenolic compounds in the manzanita eaten by the deer of the unburned chaparral. Without the high levels of phenolic compounds ingested by the unburned chaparral deer the biohydrogenation continues normally and the saturated fatty acid content of the deer muscle tissue is higher, as seen in the deer from the oak woodland. It is possible that the saturated fatty acid content of the tissues of domestic bovids could be reduced in similar fashion if the biohydrogenation of unsaturated fatty acids in the rumen could be reduced. Perhaps such a reduction could be accomplished with controlled amounts of phenolic compounds, as it was in the deer of the unburned chaparral. Meat from ruminant animals accounts form a substantial amount of the diet for Americans. Atheroma has been correlated with the intake of saturated fatty acids of a major food source perhaps some of the tendency for atheroma could be reduced.

5086. Hilty, Jodi A., and Adina M. Merenlender. 2000. **A comparison of covered track-plates and remotely-triggered cameras.** Pp. 27-31 *in:* Trans. West. Sect. Wildl. Soc., Vol. 36, Riverside, CA, Jan. 27-29.
Abstract: A study was conducted to determine the relative effectiveness of track-plates compared to cameras for detecting carnivores in California's north coast oak woodland and agriculture interface. Results from covered track-plate and remotely-triggered camera data were compared across 6 different sites. Track-plates detected fewer species, and the probability of not detecting a species that was present at a site was higher for track-plates than for camera systems. Cameras also were effective at detecting target species without bait. Use on non-baited, remotely-triggered cameras is recommended for monitoring of opossum and carnivore populations in oak woodland habitat of California.

5087. Howard, Walter E., and William M. Longhurst. 1956. **The farmer-sportsman problem and a solution.** Trans. N. Am. Wildl. Conf. 21:323-330. *Also published in* ***Calif. Farmer*** *(April 28, 1956), pp. 466-467.*
Abstract: A greater amount of private land is now closed to sportsmen, which results in the bulk of wildlife resources being unavailable to hunters because almost three-quarters of the continental U.S. is private land. This has resulted from ever-increasing hordes of sportsmen seeking free access. Payment by sportsmen for access to private land will be necessary, while landowners will need to develop fish and game as a profitable agricultural crop. Integrating wildlife management with agricultural pursuits has become more complicated; no longer can wildlife be managed merely by enforcing game laws and preserving wilderness. When wildlife on private lands is not available for utilization, other problems develop: creation of temptation for trespass; crop damage by wildlife; competition between big game and livestock for forage; and habitat damage from wildlife overpopulation. Perhaps the main obstacle to developing game management as an agricultural resource on private land is the belief that this is "commercialization" of the public's wildlife resource, which is an unfair accusation. We foresee a mutual benefit in landowners accepting the challenge of free enterprise, trying to make a profit from managing wildlife for sportsmen. This can provide an incentive for preserving more wetlands, woodlands, and other marginal areas now considered worthless. New vistas may open up if sportsmen will encourage landowners to manage their wildlife as a business and cooperating in resolving issues of fees for access, methods of take, bag limits, and so on. More restrictive regulations on take could allow more people to partake of hunting and fishing, while maintaining wildlife resources. Ingenuity on the part of the landowners will determine the value of their wildlife resources. Services and facilities available to sportsmen are important. For the most part, fish and game are a rapidly renewable resource. The creation of an incentive among agriculturists, the principal landlords of farm fish and game, will provide more opportunities for outdoorsmen as well as reduce pressures to "open up" the few remaining wild areas.

Robert M. Timm

UC Davis wildlife ecologist Walter E. Howard explains *Microtus* pit trap plot studies to UCD wildlife class field trip, January 1977

5088. Howard, Walter E., and Elbert M. Brock. 1961. **A drift-fence pit trap that preserves captured rodents.** J. Mammal. 42(3):386-391.
Abstract: The efficiency of fences of hardware cloth to direct rodents into funnel traps is discussed. A new type of pit trap that excludes birds and automatically preserves captured rodents is described. Rodents entering the trap fall through a trap door into a gallon jar containing alcohol. The pit traps primarily catch dispersing rodents; resident populations do not appear to be destroyed. Each pit trap yielded 2.5 to 45 times as many rodents as did Sherman live traps set for only one night.

5089. Howard, Walter E. 1962. **Rangeland insect and rodent pests.** Pp. 191-193 *in:* D. E. McCloud (ed.), Pasture and Range Research Techniques. Comstock Publ. Associates, Ithaca, NY.
Abstract: Rangeland experiments and seeding operations are at

times negatively impacted by rodents and/or insects. Aerial applications of rodenticide bait may aid in temporarily reducing rodent numbers, allowing establishment or recovery of forage for grazing animals. To determine or demonstrate rodent impacts on vegetation where forage is sparse, hardware cloth cages constructed of 1/4-inch or 1/8-inch hardware cloth can be inverted over small plots in autumn. To rule out the insulating effect of the wire mesh on plant growth, control cages with small holes cut to let rodents in can be established alongside exclusion cages. Photos of such cages in use at the Hopland Field Station are shown, following a single growing season. To reduce field rodent depredations on plots up to 1-2 acres in size, permanent poison-bait stations can be established 25 to 50 feet apart. Similarly, to demonstrate insect effects on range forage, the yield on fairly large areas periodically sprayed with insecticide can be compared with untreated areas. Great care should be taken with any pesticide use to avoid harm to non-target organisms.

5090. Howard, Walter E., and Ronald E. Cole. 1967. **Olfaction in seed detection by deer mice.** J. Mammal. 48(1):147-150.
Abstract: Rodent feeding on conifer seeds appears to be a significant cause of failure of reforestation efforts. This test measured the extent to which olfactory cues are responsible for rodent detection of various kinds of conifer and agricultural grain seed. Captive deer mice (*Peromyscus maniculatus*) obtained from the Hopland Field Station and from Mt. Shasta in Siskiyou County were allowed to locate seeds buried 1 to 3 inches under a layer of peat spread on a concrete floor of an outdoor pen at UC Davis. The mice were highly successful in detecting even single seeds of various types. Deer mice detect seeds by olfactory cues, the olfactory acuity is highly developed, and there is the suggestion that odor may be an important factor in the palatability of seeds.

5091. Howard, Walter E., Rex E. Marsh, and Ronald E. Cole. 1968. **Food detection by deer mice using olfactory rather than visual cues.** Anim. Behaviour 16:13-17.
Abstract: The percentage of buried conifer and agricultural grain seeds either detected or removed by ten deer mice (*Peromyscus maniculatus*) in a subdued-light environment (0.25 ft-candle) did not differ significantly from the percentage detected or removed in total darkness. No detection or removal bias occurred toward grains, regardless of whether plain seeds or seeds treated with either safflower oil or lecithin-mineral oil were offered on the first of three night tests, with grains of different treatments being offered on the subsequent two nights. The higher the percentage detection for a given type of seed the higher the percentage of detected seeds removed. The addition of safflower oil or lecithin-mineral oil improved the detection and palatability of the four types of grain used. With the four kinds of conifer seeds used there was positive correlation between seed weight and its palatability.

5092. Howard, Walter E. 1976. **Responses of coyotes to odors.** *In:* Proc. Ann. Mtng., Tech. Comm. West. Res. Proj. W-123 "Evaluating Management of Predators in Relation to Domestic Animals," Idaho Falls, ID, Sept. 16-17. 2 pp.
Abstract: Further development of protocols for testing candidate odor attractants are described, using a captive coyote colony at Hopland. The facility established makes it possible for a single observer to conduct behavioral tests while observing coyotes' response to odors placed in an outdoor test area. Behavioral responses are recorded by means of a multiple-channel event recorder activated by a keyboard of switches. In three field tests of a bone oil - oleoresin of capsicum mixture applied to the necks of sheep at Hopland, wild coyotes were found to kill treated sheep by neck-holds. Although our samples size was small, the indication is that capsaicin as applied did not repel coyotes.

5093. Howard, Walter E. 1977. **Progress in identification of coyote scent baits.** Pp. 12-17 *in:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Logan, UT, Aug. 10-11.
Abstract: Tests of captive coyotes at Hopland during 1976 and 1977 indicated interest in coyote urine, but they did not indicate coyote discrimination among male, anestrous female, and estrous female urine. In tests conducted using beagles at UC Berkeley, the dogs spent significantly more time investigating male and estrous female coyote urine than they did investigating either anestrous female urine or the control. Subsequent gas chromatographic analysis of volatiles from the three types of urine showed no important chemical differences. We surmise that whatever qualitative or quantitative difference exist between the types of urine, they are small or of a nature not detected by the chemical analysis. Lack of discrimination by coyotes may be due to their being housed as pairs in a urine-saturated kennel environment. The same types of urine were ineffective when used in the field by county and federal trappers, whereas the types of urine they normally use are effective attractants. We suspect the diet of captive coyotes may affect urine quality and thus its attractancy to wild coyotes. When fractions of estrous and non-estrous coyote urine were tested, captive coyotes at Hopland showed the greatest interest in the "acids" fraction.

5094. Howard, Walter E., Daniel B. Fagre, and Sheila M. McKenna. 1979. **Behavioral responses of coyotes to various attractants.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Coeur d'Alene, ID, Aug. 22-23. 9 pp. + figs.
Abstract: Coyotes and other canids are known to make and to respond to urine scent marks. The specific chemical compounds within urine that are most attractive are unknown, and little is known about information gained by animals investigating scent marks of conspecifics. We wish to identify attractant chemicals for the purpose of using them to make coyote control more effective and selective. Various responses made by captive coyotes toward odors have been documented (sniffing, licking-chewing, rubbing-rolling, scent-marking followed by scraping, and defecation). Captive coyotes spent more time at urine "acids" and "neutrals" fractions than at whole urine or at the "bases" fraction. Male coyotes spent more time investigating urine of estrous females, as opposed to urine of non-estrous females, during breeding season. A commercial attractant, Carman's Distance Call Lure, was significantly more attractive than any other lure. Male coyotes were somewhat more interested in odors than were females. Weather conditions did not seem to greatly affect coyotes' response to odors. On the basis of the attractiveness of several valerian oil derivatives, we have tested and found methyl ammonium valerate to be comparable in attractiveness to synthetic fermented egg and estrous urine fractions. Using odors, or the manner in which odors are presented to coyotes, to elicit specific desired behaviors, such as rub-rolling or lick-chewing, is being investigated. Finally, we are adding amino acids and sugar combinations to coyote bait posts in an effort to enhance the lick-chew response.

5095. Howard, Walter E., Daniel B. Fagre, Sheila M. McKenna, Roy Teranishi, and Edwin L. Murphy. 1979. **Behavioral responses of coyotes (*Canis latrans*) to urine fractions (Abstract).** Pp. 33-34 *in:* Abstracts, Proc. 59th Ann. Mtng., Am. Soc. Mammal., Corvallis, OR, Jun. 17-21.
Abstract: The behavioral responses of coyotes (*Canis latrans*) to paired odor stimuli, mostly derived from coyote urine, were described. The "acid" and "neutral" fractions of coyote urine from both estrous and anestrous females aroused more interest than other fractions, and the attractability of these urine fractions compared favorably to the synthetic fermented egg scent used by the U.S. Fish

and Wildlife Service. No "dramatic" response of male coyotes was elicited by estrous urine. Coyotes' interest in the urine fractions increased when the concentrations were increased.

5096. Howard, Walter E. 1983. **Viewpoint: the coyote-1080 conspiracy– an aborted attempt to drive livestock off federal lands.** Rangelands 5(3):134-135.
Abstract: The author details a series of events, following the 1972 federal ban on poisons for coyote control, that he believes represent a conspiracy to remove livestock from federal grazing lands in the U.S. The author discredits the Cain Report, a 1972 document used to support the toxicant ban for predator control. A 1982 doctoral thesis at UC Davis documented how this conspiracy was orchestrated by an individual within the federal government with the assistance of collaborators. The primary target of this conspiracy was the use of Compound 1080 (sodium fluoroacetate) in coyote control. EPA hearings on this toxicant during 1982 exposed the false charges that were levied about this pesticide during the 1970s. The author details the need for toxicants to control coyote predation on livestock. He contends that Compound 1080 is the best toxicant available, from the standpoint of safety and environmental welfare, for predator control.

Brown San Diego (left) and Al Murphy (right) examine low-cost net wire fence designed to exclude deer, Winter 1965

5097. Howard, Walter E., and Robert H. Schmidt. 1984. **Biological rationale for 1080 as a predacide.** Pp. 138-145 *in:* Proc. 11th Vertebr. Pest Conf. (D. O. Clark, ed.), Sacramento, CA, Mar. 6-8.
Abstract: Compound 1080 (sodium monofluoroacetate) is a uniquely selective predacide for controlling coyotes, compared to other predacides. In addition to discussing the biological aspects of 1080, the reasons for the current emotional-political status of 1080 are also reviewed because the biological rationale concerning 1080 has been largely determined by a conspiracy orchestrated in 1972 by an individual of the Council on Environmental Quality but assisted by others from the U.S. Department of the Interior and the Environmental Protection Agency. Many of the distortions about 1080 can also be traced to environmental organizations which still use 1080 as an issue which they can be "anti" in order to solicit funds from the public. This paper is an attempt to clarify the true biological facts about 1080 and to expose the political conspiracies against 1080 by government and environmental organizations.

5098. Howard, Walter E., and Armando Garsd. 1985. **Twenty years of fluctuations in *Microtus californicus*.** Acta Zool. Fennica 173:39-40.
Abstract: Twenty-four alcohol pit traps were set continuously since 1959 at Hopland along the boundary fences of 3.2 ha of grassland rodent enclosures to capture dispersing voles (*Microtus californicus*) and other native rodents which are examined postmortem every two months. In a time-series analysis of 4,737 voles over 19 years, and of 5,308 voles trapped over 21 years, weather played a key determinant role. The population fluctuations of these voles, and of those documented in the literature, generally cannot be described by periodic or regularly cyclic equations, but rather they are either random or occasionally pseudoperiodic. Correlations between indicators of solar activity and the nonseasonal fluctuations may represent either a direct effect of those cosmic variables or a synchronous effect of climate, physiology or diseases.

5099. Howard, Walter E., Roy Teranishi, Rex E. Marsh, and Jerry H. Scrivner. 1985. **Understanding coyote behavior.** Calif. Agric. 39(3-4):4-7.
Abstract: This paper summarizes some accomplishments of coyote research conducted at the Hopland Field Station since 1973. Brief discussions of the following subjects are included: 1) effects of predation on sheep in Glenn and Colusa counties, California, and on the Hopland Field Station, 2) killing behavior of coyotes, 3) use of coyote repellents 4) aversive conditioning in coyotes, 5) odor attractants, 6) coyote population dynamics modeling, and 7) a new predator control device.

5100. Hygnstrom, Scott E., Robert M. Timm, and Gary A. Larson. 1991. **An update on the revision of the handbook, Prevention and Control of Wildlife Damage.** Pp. 93-95 *in:* Proc. 10th Gt. Plains Wildl. Damage Control Wkshp. (S. E. Hygnstrom, R. M. Case, and R. J. Johnson, eds.), Lincoln, NE, Apr. 15-18.
Abstract: Efforts to revise the 1983 publication Prevention and Control of Wildlife Damage are described. The revised publication will contain some 83 chapters and sections dealing with methods to manage wildlife damage throughout the United States. The revision is to be a cooperative effort between the Nebraska Cooperative Extension Service and the USDA-APHIS-Animal Damage Control.

5101. Hygnstrom, Scott E., Robert M. Timm, and Gary A. Larson (Editors). 1994. **Prevention and Control of Wildlife Damage.** Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE. 848 pp.
Abstract: This comprehensive reference provides recommendations on preventing and controlling damage caused by various species of wildlife throughout North America. Major sections include Damage Identification, Rodents, Carnivores, Other Mammals, Birds, Reptiles and Amphibians, Pesticides, and Supplies and Materials. It contains chapters on some 75 species or species groups, providing details on typical patterns of damage, the animals' biology and behavior, and the methods that can be utilized to prevent or reduce damage. Damage control methods include such categories as exclusion, habitat modification, frightening, repellents, and correct use traps and toxicants. All federally registered pesticides, including both toxicants and repellents for use against vertebrate species, are listed and described. Examples of product labels are included. A list of manufacturers and distributors of products useful in wildlife damage control is included.

5102. Jaeger, Michael M., Karen M. Blejwas, Benjamin N. Sacks, Jennifer C. C. Neale, Mary M. Conner, and Dale R. McCullough. 2001. **Targeting alphas can make coyote control more effective and socially acceptable.** Calif. Agric. 55(6):32-36.
Abstract: Research at the Hopland Research and Extension Center has improved the understanding of how to reduce sheep depredation while minimizing the impact on coyotes. Analysis of a 14-year data set of HREC coyote-control efforts found that sheep depredation losses were not correlated with the number of coyotes removed in

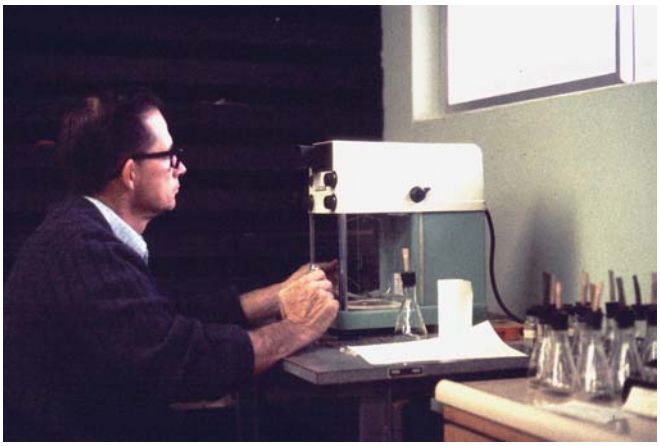
any of 3 time scales analyzed (yearly, seasonally and monthly) during corresponding intervals for the next 2 years. Field research using radiotelemetry to track coyotes supported and explained this finding. For example, in 1995, dominant "alphas" from four territories were associated with 89% of 74 coyote-killed lambs; "betas" and transients were not associated with any of these kills. Relatively few coyotes were killing sheep, and these animals were difficult to capture by conventional methods at the time of year when depredation was highest. However, selective removal of only the problem alpha coyotes effectively reduced losses at HREC.

5103. Jones, Milton B., and William M. Longhurst. 1958. **Overhanging deer fences.** J. Wildl. Manage. 22(3):325-326.
Abstract: Describes two slanting types of fences used to exclude deer from plots at the Hopland Field Station. Methods of construction, materials used and costs are explained.

5104. Kepner, Richard E., and Walter E. Howard. 1960. **Mechanical gopher-bait applicator for pastures and open fields.** Calif. Agric. 14(3):7, 14.
Abstract: This paper describes a mechanical bait applicator for controlling pocket gophers. The device makes an artificial burrow and meters poisoned grain into the burrow. Testing of the device both in California and in Colorado produced encouraging results, however additional testing is needed to determine optimum bait formulations, bait application rates, and operational guidelines under varying environmental conditions.

5105. Knowlton, Frederick F., Eric M. Gese, and Michael M. Jaeger. 1999. **Coyote depredation control: an interface between biology and management.** J. Range Manage. 52:398-412.
Abstract: Predation by coyotes (*Canis latrans*) on livestock continues to plague producers in the United States. Agricultural interests are concerned about coyote predation because sheep inventories in the U.S. have declined >85% in the past 60 years, with 25% decline between 1991 and 1996. This decline in sheep numbers has been attributed to low economic returns among producers, with coyote predation cited as a major causative factor. Generalizations about the magnitude and nature of depredations can be misleading because of the varied nature of sheep operations, including size of operation, differences in management, and environmental circumstances surrounding individual operations. Coyote depredation rates appear to be influenced by sheep management practices, coyote biology and behavior, environmental factors, and depredation management programs. Most nonlethal depredation control techniques fall within the operational purview of the producers. The major controversy regarding depredation management focuses on programs that remove coyotes to prevent or curtail predation on domestic stock, especially on public lands. Differences in the magnitude, nature, and history of problems caused by coyotes, as well as the circumstances in which they occur, dictates a need for a variety of techniques and programs to resolve problems. The resolution of coyote predation upon livestock remains controversial for producers, resource managers, and the general public. Because various segments of society attach different values on coyotes, resolution of depredations should use management programs that integrate the social, legal, economic, and biological aspects of the animals and the problem. Preferred solutions should involve procedures that solve problems as effectively, efficiently, and economically as possible in the least intrusive and most benign ways. Predation management requires a partnership among producers and wildlife managers to tailor programs to specific damage situations so the most appropriate techniques can be selected. This paper attempts to clarify the issues surrounding depredation management, synthesize past and current research, and provide information to resource managers associated with coyote depredation management. Numerous citations are made to coyote research conducted at Hopland from the early 1970s until the late 1990s. This synthesis integrates current understandings of coyote biology and behavior, the nature of depredations upon sheep producing enterprises, and the merits of various depredation control strategies and techniques.

5106. Kruse, Sheila M., and Walter E. Howard. 1983. **Canid sex attractant studies.** J. Chem. Ecol. 9(11):1503-1510.
Abstract: Behavioral studies using anestrous female beagles, and olfactory tests with dogs in the absence of females, indicate that methyl *p*-hydroxybenzoate cannot be considered a key sexual attractant for male beagles, even though this compound has been found in estrous vaginal secretions.



Guy E. Connolly

Bruce Browning, Fish & Game biologist, weighs samples on analytical balance in lab, March 1973

5107. Leopold, A. Starker, Michael Erwin, John H. Oh, and Bruce M. Browning. 1976. **Phytoestrogens: adverse effects on reproduction in California quail.** Science 191:98-99.
Abstract: Phytoestrogens, largely formonoetin and genistein, are produced in the leaves of stunted desert annuals in a dry year. When ingested by California quail (*Lophortyx californicus*), these compounds apparently inhibit reproduction and prevent the production of young that will not have adequate food. In a wet year, forbs grow vigorously and phytoestrogenic substances are largely absent. Quail then breed prolifically and the abundant seed crop carries the enlarged population through the winter.

5108. Longhurst, William M., A. Starker Leopold, and Raymond F. Dasmann. 1952. **A survey of California deer herds, their ranges and management problems.** Game Bull. 6, Dept. of Fish & Game, Sacramento, CA. 136 pp.
Abstract: Pre-settlement deer populations are described within California's major biotic communities, with deer having been most abundant in chaparral and oak-woodland zones of the coastal mountains and foothills bordering the Central Valley. Periodic fires helped maintain optimum browse and forage. The arrival of American settlers brought overgrazing, indiscriminate forest destruction, and persistent hunting. Coupled with a series of severe winters, this brought deer numbers to a low point during 1890-1910. From 1907 to 1917, effective programs of deer restoration and game protection evolved, and these are little changed today. Many thriving herds developed in mountain areas where brush had replaced the original timber. By the 1940s, practically all ranges were fully stocked and many were overstocked, resulting in periodic starvation losses, periodic disease epizootics, overbrowsing and deteriorating ranges, increasing agricultural and garden damage, and reduced herd productivity. These effects persist today. Regulations and management tools appropriate to the past should be re-evaluated and discarded or supplanted by techniques designed to meet *present*

needs, which are: to harvest a maximum annual crop of deer from existing breeding populations; and to preserve and improve the ranges with a view to supporting the largest possible breeding population in future years. Hunting regulations should be liberalized to permit a harvest of 2 to 3 times the present kill. This will necessitate harvesting some does as well as more bucks, under a program of careful, *local* regulation. A plan for subdividing the state into logical units for administering such local regulation is given. Additional techniques are applicable to some types of deer habitat: controlled burning and reseeding in chaparral; regulated livestock grazing; regulated logging; and other special procedures may be useful locally in increasing range capacity for deer. To accomplish these advancements will require trained field men, a sympathetic and cooperative attitude among all fish and game personnel, and an enlightened public.

5109. Longhurst, William M. 1953. **Planting to reduce deer damage.** Calif. Agric. 7(2):4, 15.
Abstract: Deer use of plantings of 3 strains of Sudan grass, oats, and oat-vetch mixture was evaluated by relative counts of browsed plants and fecal pellet groups. Deer browsed 5% of the Sudan 23 plants, 26% of the common Sudan, and 78% of the sweet Sudan plants measured. No deer pellets were found in the Sudan 23 plots, but the common Sudan showed 66 pellet groups and sweet Sudan 666 pellet groups per acre. Deer use was uniform on oats and oat-vetch plantings during mid-winter and spring, but became heavier on the oat-vetch mixture after mid-April as the oats matured.

5110. Longhurst, William M. 1955. **Additional records of "Tule Geese" from Solano County, California.** The Condor 57(5):307-308.
Abstract: The author collected two "Tule Geese" (*Anser albifrons gambelli*) from a flock of eight that were inhabiting a small area on the southern part of Banty Island in the marshes of the lower Napa River, Solano County, CA, on December 21, 1954. Two more were taken on Dec. 24, and the remaining four were seen again as late as Jan. 5, 1955 at the same locality. This race of the White-fronted Goose apparently has a limited distribution on both its wintering and breeding grounds. The author, in 25 years of hunting experience at this location, had not previously observed this race of geese to be present. Other authors cite wintering records from only the Butte and Sutter basins in the Sacramento Valley and from the Suisun marshes of California. Recent changes in levees around the Banty Island site may have altered the habitat so as to favor these geese. The birds were seen to remain separate from several the flocks of *A. a. albifrons* feeding on sprouting grain fields in the vicinity. The "Tule Geese" were thought to be feeding primarily on the tubers and rhizomes of rushes (*Scirpus* spp.), which they pulled up from the mud beneath the water that was as much as 1.5 ft. deep. At one spot, almost all the rushes over an area of approximately 150 ft^2 had been uprooted. Digestive system samples confirmed this observation. The skins of these specimens were placed in collections at the Museum of Vertebrate Biology, UC Berkeley, and in the teaching collections of the Depts. of Zoology at UC Berkeley and UC Davis.

5111. Longhurst, William M. 1955. **The role of parasitism in the population dynamics of a herd of black-tailed deer.** 35th Ann. Conf. West. Assoc. State Game and Fish Comm., Moran, WY, Jun. 16.
Abstract: Parasitism by nematodes is known to be an important factor contributing to the losses of Columbian black-tailed deer (*Odocoileus hemionus columbianus*) from San Francisco Bay northward in the coastal areas of California, Oregon, Washington, and British Columbia. Observations at the Hopland Field Station from fall 1951 through April 1955 shed some light on this problem. A heavy loss of deer was experienced during the severe winter of 1951-52 followed by poor fawn survival the following summer and winter. Numbers reached a low of probably between 400 and 500 head of deer by the spring of 1953, but started upward with the good fawn crop of that year and increased in 1954 despite the heavy lawn loss during that summer and a heavy buck kill in August and September. Census efforts in fall 1954 over nearly 12,000 acres including the Field Station estimated about 1 deer to 9 acres, which prorated to the Field Station's area indicated a fall population of around 550 head. Average productivity of deer was calculated from available data on fawns and does. The relatively low rate of reproduction appears largely to be a response to substandard nutrition, with a resultant lack of ovulation among the younger and older age classes of does, with only the 4-year-old does approaching theoretical maximum. Losses on the basis of cause, time age, and sex are tabulated. Natural losses, amounting to 47% of the total, were by far the most important category; these included deer that died of starvation, parasitism, disease, etc. Only one instance of predation (bobcat) was observed. Accidents of various sorts such as being caught in stock fence or trees accounted for 6% of the losses, while hunting took an additional 23%. Hunting losses are listed for bucks only, even though some does or fawns may have been shot by mistake. The removal of deer of various ages and sexes by collecting them for autopsy amounted to 24% of the total herd reduction. At Hopland, parasites can contribute significantly to losses of fawns during their first winter and to a lesser extent to the losses of yearlings during their second summer. Few older deer carry sufficient numbers of worms to be affected. The magnitude of losses involving parasitism can be increased by severe weather and overstocking conditions. In certain conditions, parasites were very likely the primary mortality factor on some deer, but in most cases the underlying cause was probably poor nutrition.


Wm. C. Dillinger, CDFG

William E. Warne (right), Calif. Dept. of Fish & Game Director, examines Clover portable deer trap with William Longhurst, wildlife biologist (in hat), along with regional Fish & Game manager Robert L. Jones (far left) and Dean Fred N. Briggs of the College of Agriculture, UC Davis, September 1959

5112. Longhurst, William M., and Walter E. Howard. 1956. **Managing deer on private land.** Calif. Agric. 10(5):4, 10.
Abstract: The annual increase in the deer population is normally 20% - 30% of the herd. Hunters usually take no more than 5% - 7% of the deer from any given area, and in many cases take less than 1%. Less than 20% of the hunters bag deer. Therefore, buck hunting in California exercises little control on the total number of deer in the state. Deer damage to crops has been reported in 53 of California's 58 counties, where deer often compete with livestock for forage and may carry diseases and parasites affecting livestock. Management

plans tailored to local conditions can provide for game harvest, thus reducing deer conflict with agriculture. The program should ideally include elements of brush manipulation and range reseeding. Hunter harvest is often the best way to control deer numbers, and it is economically advantageous as compared to deer-proof fencing or use of repellents. Several means of leasing hunting rights on private lands are described, including a public hunt at the Hopland Field Station. Ideally, regulations should provide for either-sex hunts to utilize the full potential of deer production. Such a program would not only provide a larger crop of deer for sportsmen, but also furnish landowners an economic return from the deer they support. In addition, the possibility of deer starvation during severe winters would be reduced.

5113. Longhurst, William M. 1956. **Population dynamics of deer.** Calif. Agric. 10(7):9-10, 12, 14.
Abstract: Causes of mortality in the deer population at the Hopland Field Station were studied from 1951 to 1955. Nearly half of the losses observed were the result of starvation, internal parasites, diseases, and predation. Bucks-only hunting took an additional 23%. Deer collected for research purposes amounted to an estimated 24% of the herd; if these had not been removed, likely an equal portion would have also died of natural causes. The age distribution of the Station's deer herd was defined. Population estimates indicate that the Station's fall post-hunting deer herd has fluctuated between 550 and 1,000 deer. A heavy deer loss during the severe winter of 1951-52 is described, followed by poor fawn survival. Productivity of various age classes of does was calculated. Of 40 species of parasites infecting deer at Hopland, nematodes are thought to be most serious. In general, under Hopland conditions, parasites can contribute significantly to losses of fawns during their first winter and, to a lesser extent, to the losses of yearlings during their second summer. Few older deer carry sufficient number of worms to be affected. Likewise, the magnitude of losses involving parasitism can be increased by severe weather and overstock conditions.

5114. Longhurst, William M. 1957. **The effectiveness of hunting in controlling big-game populations in North America.** Trans. N. Am. Wildl. Conf. 22:544-569.
Abstract: In recent years, wildlife managers have come to realize that it is hunting and not protection alone which is the chief management tool for the regulation and maintenance of big-game numbers. At present the concept of the ideally managed big-game herd might be described as one in which the maximum rate of turnover is maintained. A herd from which the annual production is regularly removed and which is kept in balance with its forage supply is immeasurably more vigorous and healthy than one which is lightly cropped and allowed to exceed its range capacity. In this paper, data from a survey of game administrators and technicians throughout North America are presented in an attempt to summarize the way in which hunting is currently being utilized. It is concluded that except for elk and antelope, most big game populations in North America are not being effectively managed by hunting. Even though white-tailed deer are more heavily hunted than mule deer, they seem to be more difficult to control. Whether this results from their more secretive habits, the type of cover they favor, or their tendency toward residency, thus avoiding the migrations of mule deer which make them more vulnerable to hunting, is not clear. A considerable number of states and Canadian provinces report they are still in the restoration phase of management and are attempting to increase herds to fill unused range capacity. But for the most part, the chief problem is that of under-harvest. Obstacles to full utilization include public opposition to management, insufficient or poorly distributed hunting pressure, and overly restrictive hunting regulations. The resolution of the many factors contributing to this condition is going to tax the ingenuity of big-game managers for many years to come, and it is very unlikely that sport hunting will ever fully control all of our large ungulates under some of the conditions that exist on their ranges.

5115. Longhurst, William M. 1957. **Why manage deer?** Calif. Monthly 67(June-July):39-42.
Abstract: The author reviews historical deer populations and harvest regulations in California, dating to the middle of the 19th Century. Protection afforded deer in the early 20th Century, combined with enforcement, resulted in some rangelands being overpopulated as early as the 1920s. Bucks-only hunting regulations result in an annual take of less than 5% of the deer population, having virtually no effect on deer numbers. Losses from starvation, disease, parasites, and predation are the chief regulatory factors for deer herds. Deer over-abundance has destroyed range productivity in some locations, and browse can be slow to recover to previous carrying capacity. For deer to be in balance with range resources, a deer harvest of about 30% of the population annually is needed, which necessitates shooting both sexes of deer. Only a few western states have achieved this goal; recent deer harvest in California are less than ¼ of the potential harvest that could be maintained. Deer on properly stocked range are healthier and more productive. Adequate harvest rates also minimize deer conflicts with livestock and crops. The greatest stumbling block to progressive deer management has been lack of public sympathy and understanding.

5116. Longhurst, William M. 1959. **An unusual concentration of white-tailed kites in Napa County, California.** The Condor 61(4):301.
Abstract: The author reports, in this brief note, observing a concentration of approximately 45 white-tailed kites (*Elanus leucurus*) roosting in dead eucalyptus trees on the morning of Nov. 27, 1958, on Knight Island near the marshes of the lower Napa River in Napa County, CA. While substantial numbers of this species of bird have been reported in San Diego County in later years, the species has generally been considered rather scare in California since about 1900.

5117. Longhurst, William M. 1960. **Stress studies of deer at the Hopland Field Station.** Pp. 63-66 *in:* Proc. Calif. Sect., Soc. Range Manage.
Abstract: Studies at Hopland investigating the effects of stress on deer were begun in 1951. During the winters of 1957-58 and 1959-60, penned deer were purposely crowded while also provided ample quantities of supplemental feed, in order to measure the effects of stress. In spring, crowded deer as well as controls were sacrificed and necropsied, taking multiple measures of deer health and productivity. In comparing crowded deer to controls, no significant evidence of stress was discovered. Therefore, at the densities tested and when food was not limiting, crowding did not appear to be a problem. The author speculates how stress may effect the performance and productivity of deer on rangelands.

5118. Longhurst, William M. 1961. **Big-game and rodent relationships to forest and grasslands in North America.** La Terre et la Vie 2:305-326.
Abstract: Factors most important in the environmental interrelationships of big-game animals and rodents inhabiting forests and grasslands of North America are summarized, with emphasis on food and habitat relationships. These factors include not only the effects of the habitats on the animals, but conversely the effects of the animals on their habitats and ultimately upon themselves as well. Particular emphasis is given to white-tailed deer, mule deer, moose, elk, caribou, pronghorn antelope, bison, and collared peccary. Tabular information summarizes habitat relationships of 35 species or groups of rodents and lagomorphs.

5119. Longhurst, William M. 1962. **Wildlife relationships to land use in the upper Sierra.** Pp. 23-27 *in:* Research and Land

Management in the Upper Sierra: Conference on Interrelated Problems on Natural Resources Conservation, Tahoe City, CA, May 23-27. Wildland Research Ctr., UC Berkeley.
Abstract: This publication reviews several groups of wildlife in relationship to land use in the upper Sierra Nevada. Included are big game, small game, furbearers, and fish. Topics relevant to their management or impacts on the landscape are noted: winter ranges are critical for survival of populations of the several subspecies of mule deer which utilize this area. These deer are present in large number and may have significant impacts on vegetation. Human influences have favored the buildup of deer at higher elevations, where originally deer numbers were greatest at lower elevations bordering the valleys. A large number of black bears remain present. Numbers of Sierra big-horn sheep appear static in recent years, and they are restricted to the southeastern corner of the mountain range. A small population of Tule elk in the Owens Valley has grown and virtually depleted its food supply, causing it to now come into conflict with agriculture and livestock. Beavers have had rather profound effects on certain of the mountain valleys, and in some cases must be controlled because of their damage. Mountain lions probably are less important than coyote in their impact on deer, because lion numbers are low. Coyotes destroy more deer than any other predator. Rodents, including mice, squirrels, porcupines, and pocket gophers, have some of the most widespread relationships to land use and may drastically alter vegetation. Some are important as reservoirs of disease. Because wildlife are so closely associated with land use programs, it is important to consider their effects and relationships when contemplating human use of the Upper Sierra.

Wm. C. Dillinger, CDFG

California Dept. of Fish & Game Director William E. Warne (left) and UC Davis College of Agriculture dean Fred Briggs examine experimental horizontal deer fence at Hopland, September 1959

5120. Longhurst, William M., Milton B. Jones, Ralph R. Parks, Loren W. Neubauer, and Maynard W. Cummings. 1962. **Fences for controlling deer damage.** Calif. Agric. Exp. Stn. Circ. 514, Univ. Calif. 19 pp.
Abstract: Fences are the most effective means of controlling deer damage to agricultural crops. Though construction and maintenance costs are high, fencing is economically justified for certain crops, orchards, vineyards, and irrigated pastures. The most useful designs in California are the upright and slanting or overhanging fences. Electric fences are generally not satisfactory but may be useful under certain conditions. This circular illustrates construction details of deer fences, including gates, stiles, deer guards, and drainage structures, as well as discussing important factors to consider when planning and building deer fences.

5121. Longhurst, William M. 1963. **Deer and the private landowner.** Outdoor Calif. 24(10):22-23.
Abstract: Nearly half of the estimated 1,900,000 deer in California range on private land at some time of the year, causing such problems as damage to agricultural crops, gardens, and forest tree seedlings; competition with livestock for range forage; transmission of diseases and parasites to livestock; and trespassing by irresponsible deer hunters. Deer problems may be alleviated by means of shooting, chemical repellents, or fencing. Some landowners mitigate against deer damages by leasing buck hunting rights on their properties. However, deer numbers can be controlled only by continuous either-sex hunting.

5122. Longhurst, William M. 1964. **Evaluation of the eye lens technique for aging Columbian black-tailed deer.** J. Wildl. Manage. 28(4):773-784.
Abstract: In order to evaluate the eye lens technique for aging Columbian black-tailed deer (*Odocoileus hemionus columbianus*), lenses from 83 known-age animals were fixed, desiccated, and weighed in a standardized manner. Several potential sources of error in the preparation and weighing of lenses were explored, including length of desiccating time, length of cooling period before weighing, removal of lenses from eyeballs before fixing, and freezing prior to fixing. The effects of freezing and removal of the lens before fixing were investigated on a series of domestic sheep (*Ovis aries*) eyes. Freezing had no significant effect, but it was determined that fresh lenses were easily damaged with consequent loss of weight. For statistical comparisons of the influence of sex, nutrition, body weight, and geographic variation, a mathematical expression of the lens weight-age relationship was necessary, and the equation $Y = a + b \log X$ was found to give a satisfactory representation of the data. A comparison was made with weights of lenses form 20 known-age Rocky Mountain mule deer (*Odocoileus hemionus hemionus*) from Utah, and significant differences were found. Lenses from male and female deer differed significantly in weight. The effects of nutrition on lens weight are not clear cut, and even though there is a good general correlation with body weight, trends vary with increasing age. Using the regression, a test was made of the usefulness of the lens technique by estimating the ages of the known-age deer. The margin of error was found to be directly proportional to age, but did not bear a constant relationship and increased rapidly in deer older than 5 years. Accuracy was improved by comparing males and females with their appropriate regressions. In general, this technique is considered to be satisfactory for aging deer at least through 5 years, especially if only year classes are desired.

5123. Longhurst, William M., Marvin Goldman, and R. J. Della Rosa. 1966. **Comparison of the environmental and biological factors affecting the accumulation of ^{90}Sr and ^{137}Cs in deer and sheep.** Pp. 635-648 *in:* Proc. Int. Symp. on Radioecological Concentration Processes, Stockholm, Sweden, Apr. 25-29.
Abstract: Factors affecting the accumulation of ^{90}Sr and ^{137}Cs in deer and sheep, on contrasting natural diets, have been under investigation since 1951 as an important phase of a continuing study of the comparative biology of these two species of ruminants. The present study was done at the Hopland Field Station of the University of California, located in the northwestern part of the state. The species studied were the native Columbia black-tailed deer (*Odocoileus hemionus columbianus*) and the domestic sheep (*Ovis aries*), which forage together over the 5,000 acres of range land of the field station. Studies encompassing several hundred of these two ruminants have shown that although they occupy the same areas, they are separated ecologically by their food preference. Examination of ruminal contents throughout the year has indicated that deer are primarily browsers, with some 70% of their intake consisting of the leaves and twigs of woody forage plants. In contrast, the diet of sheep is approximately 80% grass. Although deer eat some grass

(18%), and sheep consume a certain amount of browse (7%), their intake of fallout radionuclides is derived largely from the dominant forage species in their diets. Additionally, a number of other environmental and species-specific biological factors have been studied. These include the relative effect of: 1) time of birth and rate of growth in relation to local weather influence on fallout patterns; 2) body sizes and metabolic rates which largely control the amount of forage intake; 3) physiology and morphology of the digestive tract; 4) phenology of forage plant growth; 5) nutritive value and palatability of forage plants as they influence animal selection; and 6) extent of foliar and root accumulation of radionuclides in forage plants. With the exception of *Ramalina reticulata*, a lichen of some importance to deer, it generally has been found that accumulation levels of strontium and cesium are similar in the forage plants studied. While the $^{137}Cs/^{90}Sr$ ratio in pooled samples of important forage plants ranged from about 1·2 to 1·8 in 1964-5, and was similar to the ratio in local rainfall, the ^{90}Sr concentration (pCi/g dry wt) ranged from a low value of 1·5 in the fall of 1964, to a peak of 5·5 in the spring of 1965. In contrast, ^{90}Sr in West Coast human diets, which obviously are at a different trophic level, increased only 50% during the same period. The period of rapid skeletal growth in sheep is between January and May, and for deer is between May and the following January. Therefore, maximum skeletal growth of sheep is in phase with peak radioactivity levels in forage to a greater extent than it is in deer. Although the interaction of these factors is necessarily complex, a model of ^{90}Sr accumulation in the two animals is primarily a function of the timing of radionuclide intake in relation to the rate of skeletal growth. In the case of ^{137}Cs, which has a relatively rapid turnover time, animal soft tissues primarily reflect intake levels over a short time (about 1 to 2 months) prior to sampling.

Jeff Lee, SR Press Democrat

Visiting scientist John H. Oh demonstrates selective deer feeding on madrone leaves after treatment with an experimental deer repellent, October 1971

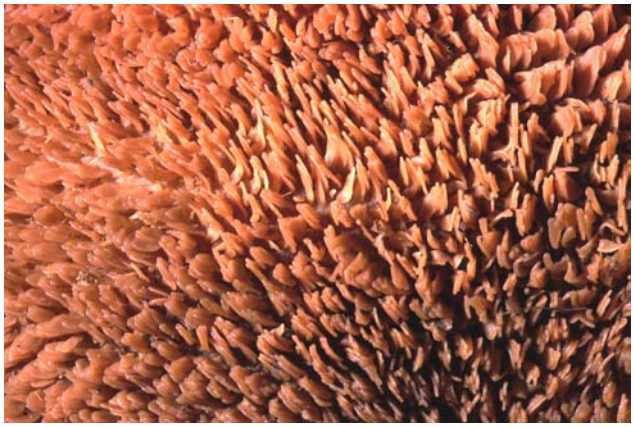
5124. Longhurst, William M., H. K. Oh, Milton B. Jones, and Richard E. Kepner. 1968. **A basis for the palatability of deer forage plants.** Trans. N. Am. Wildl. Nat. Res. Conf. 33:181-192.
Abstract: Ruminants, including deer are known to prefer plants which are especially nutritious. However, the nutrient content of plants is not always correlated with their palatability since unpalatable species have often been found to contain high levels of nutrients. Therefore nutrient content alone does not always account for differences in palatability. Olfaction has been found to be the primary sense used by deer to discern the plants they prefer. Certain of the volatile substances in plants which contribute to their aroma have also been found to inhibit the growth of rumen bacteria. Likewise, among the plants studied, good correlation has been found between their unpalatability and the extent to which they inhibit the growth of rumen microorganisms. The least palatable are the most inhibitory. It is doubtful, however, that deer through olfaction are able to detect the presence of nutrients or digestive inhibitors in plants directly and may be depending on other association indicators. If deer can forage on a mixed diet of various plant species, they are able to tolerate small amounts of those that are unpalatable. However, if competition for the more palatable species is severe and deer are forced to feed largely on unpalatable plants that are inhibitory on rumen function, losses can result. Different species of ruminants, harboring differing complements of rumen microorganisms digest plants at different rates. Examples are given on the relative ability of deer and domestic sheep to digest grass and browse and this is thought to influence their preferences for these kinds of forage. Other factors such as the biogenesis of inhibitory compounds in maturing vegetation or even soil fertility can also affect palatability. It is suggested that plants have developed physiological defense mechanisms through the accumulation of compounds which inhibit digestion by rumen bacteria. The flora of New Zealand which has been decimated by introduced herbivores is given as an example of a plant association that had not developed this sort of protection through natural selection with exposure to animal use.

5125. Longhurst, William M., and W. L. Robinette. 1968. **Management needs.** E. African Agric. and Forestry J. XXXIII:284-286.
Abstract: There is a critical need for long-range planning, for stated objectives, and for integration of wildlife with other land uses in East Africa. The chief threat to wildlife is restriction of habitat through ever-spreading subsistence agriculture and livestock operations. Only through maximum utilization can sufficient economic value be developed for wildlife for it to compete with other demands for land use. Such values can most logically be developed through tourism, including game viewing and sport hunting, as well as harvesting surplus wildlife stocks for commercial meat sources. Legislation to control unplanned land settlement is needed immediately. Specific beneficial changes in sport hunting regulations are required. Additional sources of fees from wildlife uses should be developed. Wildlife management is big business, and it should be treated as such. Operations should be designed to return maximum benefits to local people.

5126. Longhurst, William M., Vincent Schultz, and Guy E. Connolly. 1968. **Accumulation of strontium-90 in yearling Columbian black-tailed deer 1960-67.** J. Wildl. Manage. 32(3): 621- 623.
Abstract: In continuation of a long-term study of ^{90}Sr accumulation in deer on the Hopland Field Station, analytical data are presented on yearling mandibles collected from 1961-1967. The highest ^{90}Sr levels occurred in deer collected in 1963. Significant variation in ^{90}Sr burdens among individual deer was observed.

5127. Longhurst, William M., John H. Oh, Milton B. Jones, and Richard E. Kepner. 1969. **Deer forage palatability, digestibility, and management implications.** Pp. 1-7 *in:* Transactions, California-Nevada Sect., The Wildl. Soc. (J. Yoakum, B. Browning, R. Miller, and A. S. Leopold, eds.), Berkeley, CA, Feb. 28 - Mar. 1.
Abstract: To be palatable, deer forage plants must also be digestible. Digestibility in turn has been found to depend to a large extent on the balance between nutrients which favor the growth of rumen microbes and any inhibitory substances which plants may contain that depress microbial growth. Deer select their forage primarily by olfaction and secondarily to taste and sight. The inhibitory substances which have been isolated thus far fall into two general groups of chemicals,

essential oils and phenolic compounds. However, only a few compounds in these large groups have been found to be inhibitory. Soil fertility, particularly the level of nitrogen available to plants, seems to have a marked effect on palatability, however, this is thought to result from an improvement in the nutrient level accumulated in the plants. Deer can tolerate the inhibitors in unpalatable plants if they only eat a small amount at a time, and they appear to thrive best on a mixed diet. The development and accumulation of microbial inhibitors in plants is considered to be a form of physiological defense against animal use that has had a bearing on natural selection. Conversely, natural selection has operated to favor strains of deer that are able to make the best use of the available plants. An understanding of these relationships should be useful in planning management programs.



Guy E. Connolly

Lining of deer rumen, from deer harvested for research in December 1973

5128. Longhurst, William M. 1970. **Book Review: Comparative Nutrition of Wild Animals.** J. Wildl. Manage. 34:663.
Abstract: The material, presented as separate papers, covers a diverse array of topics ranging from diets of laboratory primates and nutrition of zoo animals to a report on wild reindeer in Norway, ptarmigan in Iceland and Scotland, and discussion of rearing and utilizing eland in the United States. Collectively, papers presented in the proceedings of this symposium are highly recommended to those interested in comparative nutrition.

5129. Longhurst, William M., and Guy E. Connolly. 1970. **The effects of brush burning on deer.** Cal-Neva Wildlife 1970, pp. 139-155.
Abstract: Approximately 1,400 acres of spot burns (1 to 100 acres each) were created on a 3,000-acre chaparral area adjacent to the University of California, Hopland Field Station in southeastern Mendocino County and southwestern Lake County from 1963 through 1968 in order to observe the response of the resident deer (*Odocoileus hemionus columbianus*) population to brush burning. Observation of the deer population responses were continued through 1969. The vegetation on the study area consisted mainly of chamise (*Adenostoma fasciculatum*), live oak (*Quercus wislizenii*), scrub oak (*Q. dumosa*), buckbrush (*Ceanothus cuneatus*), manzanita (*Arctostaphylos* spp.), and knobcone pine (*Pinus attenuata*). The health and productivity of the deer population on the study area were compared with those observed in deer on the lower part of the Hopland Field Station where the cover was primarily oak woodland with a grass understory and where burned brush was not available, by means of herd composition counts taken each April, July, and October. Body weights, rumen fill, blood urea nitrogen levels, and pregnancy rates were also determined in samples of deer collected from these two areas as well as from an unburned chaparral area approximately 2 miles east of the burn area. The plant species composition of rumen contents was also determined. Throughout the course of this study, the general health of deer on the burned chaparral area appeared better than that in the unburned chaparral but poorer than that observed on the Hopland Field Station. Year-to-year variations within each of the three areas studied was found to be as great as overall differences among habitat types. Although this burning program did not markedly improve the health and productivity of the deer population in the study area, such burning increases hunter access to deer in chaparral areas. This increased accessibility of deer for hunters may be equal in value to the forage improvement resulting from burning programs. An analysis of brush treatment costs, however, indicates that such management is economically questionable under current hunting regulations under which only adult males constituting 10 to 15% of the deer population are legal game. It is suggested that a major goal of chaparral management programs should be to increase the availability of grasses and forbs to deer for as much of the year as possible.

5130. Longhurst, William M. 1975. **Burning chaparral for deer habitat improvement.** Agricultural Extension, Univ. of Calif. Wildland Resources 3(2):1-3.
Abstract: Brush habitat improvement for deer on private lands combined with realistic deer herd management is attractive for many reasons. For instance, hunters have shown that they are willing to pay substantial fees for access to deer hunting. Profit from harvest of a renewable resource, deer, would promote habitat improvement on private lands that include a large portion of the chaparral in California. The public would benefit from a program inspired by this economic incentive.

5131. Longhurst, William M. 1976. **Wildlife research is diverse, productive.** Calif. Agric. 30(7):9-10.
Abstract: Research at the Hopland Field Station has explored the biology and ecology of wildlife species, especially deer, and their interaction with agriculture. Studies with deer included parasites and diseases, nutrition, habitat manipulation, and relationships to agriculture. Coyote studies have explored how coyotes attack and kill sheep, the impact of their predation on the sheep industry, and effectiveness of control by use of various attractants and repellents.

5132. Longhurst, William M., Edward O. Garton, Harold F. Heady, and Guy E. Connolly. 1976. **The California deer decline and possibilities for restoration.** Pp. 74-103 *in:* Cal-Neva Wildlife, Vol. 12, The Wildlife Society, Fresno, CA, Jan. 29-31.
Abstract: The apparent decline of deer numbers in California which started about 1960 is attributed primarily to a diminishing food supply and loss of habitat. The influences of fire, logging, and livestock grazing starting in the late 1800s altered pristine vegetation on forests and rangelands which originally supported relatively few deer, triggering growth of successional food plants which deer could use. Changes in the patterns of burning, logging, and grazing plus a shift from sheep to cattle on rangelands all have contributed to lowering the production of deer food plants. These changes have been accompanied by unfavorable weather patterns which have apparently augmented the decline. Continued lack of an adequate hunting programs to utilize deer effectively has led to overstocked ranges where severe intraspecific competition for existing forage supplies has existed for many years. Deer have contributed importantly to the decline of their own range condition. Changes in land ownership and use objectives, silvicultural practices, and construction of highways and water projects have all played a part in the loss of deer habitat. The relative importance of the major mortality factors was evaluated including highway and railroad kills, accidents, diseases and parasites, predation, legal and illegal hunting, and effects of inadequate nutrition. Losses associated with nutritional deficiencies were considered to be paramount although other loss factors collectively account for a large number of deer. Restoration

of deer numbers will depend upon reversing the down trend in the factors which produce the successional stages of vegetation which deer require. Changing these trends will often be expensive and funds will be largely wasted unless control of deer numbers through hunting can be achieved. An adequate public information program is imperative to convince the public and the legislature of the need to change the hunting program to one of full harvest of both sexes of deer. Controlled burning, modification of reforestation practices, the use of controlled livestock grazing and agricultural planting of deer forage supplements all have potential for improving deer food supplies. It is doubtful if state or federal agencies will have the funds or manpower to restore deer habitat on the necessary scale and private land owners should be encouraged through economic incentives to do the job on their own lands. Until a workable hunting program is operating, efforts to control deer losses from other causes will serve little purpose except to intensify the level of intraspecific competition for food. The decline of deer in California has by no means reached its end point and we predict that it will continue if strong measures are not taken to alleviate it.

5133. Longhurst, William M. 1978. **Responses of bird and mammal populations to fire in chaparral.** Calif. Agric. 32(10): 9-12.

Abstract: Wildlife use of chaparral is discussed in terms of how it changes with the occurrence of periodic fire. Uses of chaparral in various stages of maturity following fire and regrowth are presented for mammals and birds in tabular format, based on wildlife at the Hopland Field Station and the adjacent Cow Mountain Recreation Area. The responses of various species to fire and its effects in chaparral communities are determined by their respective habitat preferences and by their movement patterns, reproduction, and food habits. For example, relatively few species are adapted to extensive stands of mature chaparral, while many species thrive in younger chaparral stands, particularly if there is an interspersion of age classes of brush or there are openings with grass and herbaceous plants present. At Hopland, chaparral grows back rapidly after burning; within 10 years it is difficult to determine to what extent most plants were burned. If during burning islands of brush are left unburned, or if the fire follows an irregular course, the margin between the burned and unburned brush will be more complex. Then, the amount of "edge" habitat will increase, and the habitat for a number of mammals and birds will improve. Following fire, an abundance of seedlings and sprouts, together with numerous kinds of grasses and herbaceous plants that grow in burned areas, provide a new and abundant food source for deer, rodents, and a number of birds. The new growth is significantly more nutritious that old-growth brush. The increase in carrying capacity for deer is especially dramatic: at Hopland, census data indicate deer numbers will increase from about 20 per square mile in mature chaparral to 60 per square mile in chaparral that has been opened up by fire. When extensive areas are converted from brush to grassland, birds and mammals that are adapted to grassland will thrive, but the habitat will not be favorable for edge-adapted species. Species that have limited home ranges, restricted to a few acres, are more apt to be affected significantly when fire occurs in chaparral. In contrast, the winder-ranging animals have the ability to move about to seek the habitat conditions they require.

5134. Longhurst, William M., Guy E. Connolly, Bruce M. Browning, and Edward O. Garton. 1979. **Food interrelationships of deer and sheep in parts of Mendocino and Lake Counties, California.** Hilgardia 47(6):191-247.

Abstract: Between 1951 and 1975, range forage interrelationships and food habits of black-tailed deer and domestic sheep were studied on the Hopland Field Station. Other nearby areas with contrasting cover types were compared. Data were collected on percent of volume and frequency of occurrence of forage plant species in samples of rumen contents taken from animals collected on the various range types. Browse preferences were compared in a series of "cafeteria" feeding trials with penned animals, and correlations with phosphorus and protein content were tested. Little significant forage competition between deer and sheep was found, although chaparral browse was limited. In general, diets of these animals were complimentary, with deer relying primarily on browse and sheep on grass. In other range types, deer had a wide latitude in their dietary patterns, depending upon availability of preferred forage species. In browse preference feeding trials, where grasses were excluded from the diet of sheep, both deer and sheep tended to select or reject the same browse species; their palatability did not correlate with phosphorus or protein content when measured on a dry weight basis. However, deer preferences ranking correlated significantly with plant protein content determined on a green weight basis. Relationships between forage consumption and forage production on the Field Station were also evaluated. Production of all forage classes except chaparral browse exceeded estimated consumption by wide margins. However, combined browsing by sheep and deer substantially reduced oak seedlings and will eventually lower browse, mast, and lichen production. Sheep grazing on Hopland Field Station maintains grassland in a productive seral stage, which raises the carrying capacity for deer over that which would exist without livestock.

A. H. Murphy

Guy Connolly (left) and Bill Longhurst (right) observe a captive deer's food preference between two choices, 1969

5135. Longhurst, William M. 1980. **Ch. 36. Management of wild mammalian species.** Pp. 675-693 *in:* H. H. Cole and W. N. Garrett (eds.), Animal Agriculture: the Biology, Husbandry, and Use of Domestic Animals. W. H. Freeman and Co., San Francisco, CA.

Abstract: The management of wild mammals for human benefit is a profession that involves many scientific disciplines and that has developed over a long period of time. Like many other agricultural practices, it is designed to make the land produce a sustained crop– in this case, wildlife that can be utilized for recreation, esthetic purposes, or food. The chapter describes the history of wildlife management and the biological basis for managing wild mammals. This includes comparison of wild mammals and livestock, discussion of management objectives, food chain relationship, adaptations, resource competition, and population trends. Habitat manipulation and predator control and discussed as important management methods. The scope of management and selected examples are given for North America, Mexico and Central and South America, Europe and Russia, Africa, and Australia and New Zealand. Future trends in

management of wild mammals are discussed.

5136. Longhurst, William M., R. E. Hafenfeld, and Guy E. Connolly. 1982. **Deer-livestock interrelationships in the western states.** Pp. 409-420 *in:* Proc. Wildl.-Livest. Relationships, Symp. 10 (J. M. Peek and P. D. Dalke, eds.), Coeur d'Alene, ID, Apr. 20-22, 1981. Univ. Idaho.
Abstract: Historical relationships of livestock grazing on deer ranges in 11 western states are summarized and compared with the effects of fire and logging. The relatively high deer populations which now occur in the West apparently did not exist until a significant amount of range vegetation was changed from its pristine state by European man and his livestock. Although fire was factor on western ranges before the arrival of livestock in the last 200-300 years, it did not trigger the growth of the kinds of successional forage plants necessary to produce a quantum increase in deer carrying capacity. When livestock reduced the density of native perennial grasses and settlers and miners opened the old-growth forests, the stage was set for deer to increase. Nearly 70% of the land area of the western states is grazed regularly by livestock, usually annually and for only part of the year. The effects of fire and logging may persist much longer than those of grazing, but these other influences affect relatively few acres each year. The cumulative impact of long-term livestock use is likely the paramount influence which has produced and maintained seral vegetation for deer. The results of inter- and intra-specific competition for range forage are compared. Comparisons are also made of successional relationships on several of the major vegetational types. The potential impact of the shift in the balance of sheep and cattle on western ranges is discussed. Even though sheep diets usually overlap with deer more than cattle diets, at moderate stocking rates we believe that sheep grazing may be more beneficial to deer than is cattle grazing. We suggest that the potential for prescribed livestock grazing as a management tool to maintain quality deer forage needs more exploration.

5137. Longhurst, William M., and Guy E. Connolly. 1982. **Deer (pellet count).** Pp. 247-248, 353-356 *in:* D. E. Davis (ed.), CRC Handbook of Census Methods for Terrestrial Vertebrates. CRC Press, Inc., Boca Raton, FL.
Abstract: The authors discuss the pellet count method of censusing deer populations. They list and discuss the assumptions inherent in this census technique, noting that these assumptions may be more valid for some deer populations than for others. Steps involved in the pellet group count method are listed in detail, noting that this method has frequent application. Mathematical formulas are given the permit calculation of number of deer present, total animal days of use, and average number of deer present between two dates. Formulas to determine the variability of the estimate are also provided. If variability is excessive, instructions are provided on calculation of the number of sample plots needed to reach the required level of accuracy. The authors note that only the pellet count method, when compared to other deer census methods, has been shown to provide realistic annual estimates while also requiring the least effort.

5138. Manley, Patricia N. 1987. **Dependence of breeding birds on the density of oaks.** Oaks 'n' Folks 2(2).
Abstract: This article is a brief progress report on a study of breeding birds in oak woodland habitat at Hopland. The study's goal is to identify bird species most sensitive to habitat degradation, determine habitat specialists, and to clarify ecological interrelationships that exist in oak woodlands. Data analysis, currently in progress, is expected to contribute to creation of future management guidelines. At Hopland, it has been noted that bird species richness increases with an increase in elevation.

5139. Mansfield, Terry M. 1974. **A comparison of black-tailed deer fawns from oak-woodland and chaparral vegetation types.** M.S. Thesis, Univ. Calif. Davis. 60 pp.
Abstract: The physical condition of black-tailed fawns (*Odocoileus hemionus columbianus*) was evaluated during spring and fall, using a series of physical parameters. Condition of fawns from oak woodland was compared to those from chaparral areas. Results obtained in this study indicate that 1) no significant differences existed in body weight or skeletal growth between fawns from the two study areas; 2) oak-woodland fawns collected during the fall period were substantially older than chaparral fawns collected during that period; 3) the level of femur marrow fat differed seasonally and with the age of the fawns; 4) there exists an inverse relationship between fat and water and fat and non-lipid residue in femur marrow of black-tailed deer; 5) the non-lipid residue component appeared to be greater in fawns than in mature deer; 6) a modified Babcock procedure can be used to quantify femur marrow fat levels in a wild ruminant species; 7) oak-woodland fawns had significantly higher levels of femur fat during the fall period; 8) the fat content of muscle tissue of oak-woodland fawns was significantly higher than that of chaparral fawns during the spring period; 9) the value of rumen fill expressed as a percent of body weight is uncertain as no significant differences were observed between fawns from the study areas during the spring or fall collection periods; 10) the diet of oak-woodland fawns contained a greater diversity of forage species than the diet of chaparral fawns; 11) volatile fatty acid content and caloric value of rumen fluid from oak-woodland fawns tended to be greater than those of chaparral fawns; 12) packed cell volume levels of the fawns collected were similar to levels given for mule deer; 13) fawns from the oak-woodland area were commonly parasitized by bodyworms while chaparral fawns were not; 14) the parameters which best measured physical condition were femur marrow fat content, muscle tissue fat content and rumen fluid volatile fatty acid content.


Guy E. Connolly

UC Davis graduate student Terry Mansfield conducts lab analyses on samples to determine deer fawn health, October 1973

5140. Mansfield, Terry M., Guy E. Connolly, and William M. Longhurst. 1975. **Condition of black-tailed deer fawns from oak woodland and chaparral habitat types.** Pp. 1-12 *in:* Trans. West. Sect. Wildl. Soc. and Am. Fish. Soc., Sacramento, CA, Jan. 24-25.
Abstract: The physical condition of black-tailed fawns (*Odocoileus hemionus columbianus*) from oak woodland and chaparral areas was evaluated during spring and fall, using a series of physical parameters: whole and field dressed weight, mandible and femur length, blood urea nitrogen level (BUN) and packed cell volume of the blood, rumen fill, volatile fatty acids (VFA) in rumen fluid, and fat content of femur marrow and muscle tissue. The plant species composition of rumen contents was also determined. The physical condition of oak woodland fawns appeared better than that of chaparral fawns, as indicated by significantly higher ruminal VFA,

BUN, femur marrow fat, and muscle tissue fat levels in animals from the oak woodland. Fat and dry matter content of femur marrow were highly correlated. Seasonal differences in the diet of oak woodland fawns were observed, while chaparral fawns relied heavily on browse both in spring and fall. Based on age estimates from eye lens and body weights, fawns in the oak woodland were born 18 days earlier than those in chaparral.

5141. Mansfield, Terry M. 1990. **Politics and animal damage control: the California lion case.** Pp. 38-43 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: Management of predatory wildlife in California has long been a controversial issue. In recent years, public concern has been focused on both the species and the control methods used. Coyotes, mountain lion, and black bear cause considerable damage to property annually. Despite a tendency for the number of confirmed damage incidents caused by lions to double every 5-6 years, politics, rather than objective information, has shaped some of the laws and policies related to controlling lion damage. During the period 1985-1988, an average of 132 confirmed damage incidents occurred and 55 lions were taken annually. Control of wildlife damage is conducted pursuant to state laws and regulations adopted by the Fish and Game Commission. In recent years, county governments have influenced animal damage control efforts by adopting ordinances which restrict the use of traps. A statewide initiative slated for the June 1990 ballot would specifically prescribe the methods for taking mountain lions causing damage. Both damage control efforts and sport hunting of lions were challenged in court by animal protection groups. It is anticipated that state and federal agencies responsible for animal damage control programs will continue to receive political pressure in California. This paper examines the politics of mountain lion damage control in California.

5142. Marsh, Rex E., Walter E. Howard, Sheila M. McKenna, Barbara A. Butler, and Douglas A. Barnum. 1982. **A new system for delivery of predacides or other active ingredients for coyote management.** Pp. 229-233 *in:* Proc. 10th Vertebr. Pest Conf. (R. E. Marsh, ed.), Monterey, CA, Feb. 23-25.
Abstract: Preliminary trials suggest that the delivery system or unit described may prove to be highly selective and effective system for delivering drugs or chemicals to coyotes. The goose egg-size unit's selectively and effectiveness relies heavily on a newly developed synthetic olfactory coyote lure based on trimethylammonium decanoate (TMAD). The coyote is attracted to the unit, which is placed at ground level, by this highly selective scent lure which elicits a biting and chewing behavior. When a coyote bites or chews the exposed part of the unit, it punctures a plastic reservoir packet containing 10 to 15 ml of viscous sucrose liquid, which serves as a taste attractant, a carrier (diluent) of the active ingredient (i.e. toxicant, chemosterilant, etc.) and as a way of diluting the toxicant, since the amount of active ingredient consumed depends upon the amount of liquid consumed. The sucrose is avidly consumed by coyotes, insuring that coyotes will ingest most of the active ingredient.

5143. Marsh, Rex E., Robert H. Schmidt, and Walter E. Howard. 1987. **Secondary hazards to coyotes of ground squirrels poisoned with 1080 or strychnine.** Wildl. Soc. Bull. 15(3):380-385.
Abstract: California ground squirrels (*Citellus beecheyi*) were laboratory fed either strychnine or Compound 1080-treated baits in amounts representative of low- or high-consumption rates expected to occur in a control program. Acute and chronic secondary toxicity was subsequently evaluated with captive groups of 4-7 coyotes (*Canis latrans*). In these acute tests, a single feeding of two squirrels, which had consumed either a low (0.5 mg) or high (3.0 mg) lethal dose of 1080, was fed to each coyote of the test groups. No mortality occurred in the coyotes given two low dose squirrels, but 5 of 6 coyotes that were given 2 squirrels receiving the 1080 high dose (i.e., 6 times the low dose) died. In the chronic 1080 test, 1 of 7 (14.2%) coyotes that consumed a low-dose squirrel for 5 consecutive days died. This suggests little secondary hazard from 5 low (0.5 mg) multiple doses. No mortality resulted when 4 coyotes were fed 2 strychnine-killed ground squirrels that had consumed a low dose (1.0-2.7 mg), and 1 death of 4 coyotes occurred in those coyotes receiving 2 high dose (5.0-7.5 mg.) squirrels. In the chronic test the 5 coyotes receiving one low dose squirrel for 5 consecutive days survived. All 3 strychnine secondary tests combined resulted in 1 fatality of 13 (7.7%) coyotes. This appears in part to be linked to the coyotes' rejection of gastrointestinal tracts containing strychnine. Minimal secondary hazards existed from strychnine-killed ground squirrels. In situations where strychnine and 1080 would be equally effective for squirrel control, strychnine might be the best option where secondary hazards to coyotes are of special concern. This assumes that strychnine use in that particular situation does not present potential hazards of a different kind that would outweigh any secondary hazards. The results indicate that if bait (toxicant) consumption by ground squirrels can be kept minimal without reducing the effectiveness of control programs, potential secondary toxicity to coyotes and presumably domestic dogs would be low. This could be achieved by reducing toxicant concentration in the bait and/or reducing the amount of bait applied. A third possibility that is suspected of reducing bait consumption is to sparsely broadcast the bait as opposed to spot baiting.

5144. Massey, Brian N., Floyd W. Weckerly, Charles E. Vaughn, and Dale R. McCullough. 1994. **Correlations between fecal nitrogen and diet composition in free-ranging black-tailed deer.** Southwestern Naturalist 39(2):165-170.
Abstract: Correlations between fecal nitrogen (N) and diet composition of deer (*Odocoileus hemionus columbianus*) were examined to gauge how well fecal N could predict diet quality. Correlation coefficients were generally weak and inconsistent between study years. Diet composition variables were significant predictors of fecal N but the coefficients of determination were small (0.16 in summer, 0.31 in winter). Fecal N appears to be useful only for confirming broad (i.e., winter to summer) seasonal trends in diet quality for free-ranging cervids.

5145. McCullough, Dale R., and William J. Carmen. 1982. **Management goals for deer hunter satisfaction.** Wildl. Soc. Bull. 10(1):49-52.
Abstract: Public deer hunters utilizing the Hopland Field Station in 1980 were surveyed regarding hunter satisfaction. The goal was to determine the management practices that promote the quality and satisfaction of the hunting experience, and to evaluate the compatibility of such practices with sound deer management. Quality of the hunting experience was most influenced by perceived deer population and secondarily by the killing of a deer. Only about 28% of hunter satisfaction was accounted for in this study, suggesting that many aspects of hunter satisfaction are beyond the wildlife manager's control. Because kill rate and population size in the field cannot be maximized simultaneously, managers face a dilemma and must establish a combination of variables that optimize benefits from a given deer population unit.

5146. McCullough, Dale R., and Paul Beier. 1986. **Upper vs. lower molars for cementum annuli age determination of deer.** J. Wildl. Manage. 50(4):705-706.
Abstract: Ages were determined for 23 black-tailed deer (*Odocoileus hemionus columbianus*) and 14 white-tailed deer (*O. virginianus*) by examination of cementum annuli of both upper and lower first molars. Although estimated ages were virtually the same

for both upper and lower molars, the clarity of annuli was significantly greater in upper molars for both species.

5147. McCullough, Dale R. 1987. **The theory and management of *Odocoileus* populations.** Pp. 535-549 *in:* Biology and Management of the Cervidae. Research Symposia of the National Zoological Park (C. M. Wemmer, ed.), Smithsonian Inst. Press, Washington, D.C.
Abstract: Deer of the genus *Odocoileus* are the most important wild ungulates in North American in both numbers and economic value. A pluralistic society has placed conflicting demands on the wildlife manager to be all things to all people. The tradeoffs of deer population management are low residual populations yielding high recruitment rates, intermediate residual populations yielding intermediate recruitment rates, or high residual populations yielding low, zero, or even negative recruitment rates. Which of these situations is desirable depends upon the goals of the management program. The traditional logistic model is not sound for managing populations of K-selected mammals such as *Odocoileus*. A deterministic model based on productivity and potential yield curves for mule and white-tailed deer is presented to predict population responses to various exploitation rates, assuming hunting to be the only source of mortality. In these K-selected species relatively small changes in reproductive potential have relatively large impacts on maximum sustained yield towards K, and may shift in that direction which leads to greater susceptibility to over-exploitation. Deterministic predictions are discussed, as well as influences and effects of residual population, stochasticity, and functional refugia.

5148. McCullough, Dale R. 1991. **Management of wildlife population dynamics for exploitation and non-consumptive use.** Pp. 125-128 *in:* Wildlife Conservation: Present Trends and Perspectives for the 21st Century (N. Maruyama et al., eds.), Tskuba and Yokohama, Japan, Aug. 21-25, 1990. Inter. Congr. of Ecol. (Intecol '90), Japan Wildl. Res. Cent., Yushima, Bunkyo-Ku, Tokyo, Japan.
Abstract: Human population growth is increasing pressure on areas managed for natural resources. Future conservation of wildlife will require that we be much better at husbandry, because of isolation of parks and reserves, severed ecological loops, etc., that accompany land use changes. In developing countries, driven by poverty and need, people are encroaching into parks for poaching, resource gathering, livestock grazing, or agriculture. In the developed world, recreation and aesthetics of wildlife are more important with consumption being a by-product. However, growth of animal protection and animal rights movements have become a major challenge to hunting and other consumptive uses of wildlife. The conflict between protectionist and consumptive philosophies is unfortunate because complex landscape mosaics call for complex management. The simple, intuitively appealing notion that if wildlife is threatened it should be protected is ecologically naive and disastrous economic and social policy. In this article, the author discusses population dynamics conflicts and the incompatibility between management for high yield vs. aesthetic values of K-selected species (those with long lifespans and low reproductive rates, e.g., large-hooved animals and carnivores– species of special tourist attractiveness). Populations of such animals that are hunted exhibit behavioral changes, including evasive behavior, that make they hard to view. The difficulties of multiple use management are discussed. Such a strategy functions reasonably well as long as land is readily available and land use pressures are low. However, as public land becomes scarce relative to human demands, decision-making shifts progressively toward political solutions that are divorced from biological considerations. The alternative is to divide land into units, each of which has a designated predominant use, e.g., wildlife. Parks and reserves can be protected for aesthetic values and animals for viewing purposes; adjacent units can be designated for sustained yield to serve as dispersal sinks to control against excessive populations in parks. Hunting and harvest strategies under such a management system are discussed.

5149. McCullough, Dale R., and Floyd W. Weckerly. 1991. **Hopland field station deer studies.** Pp. 63-65 *in:* Proc. Columbian Black-Tailed Deer Workshop (R. H. Schmidt, R. M. Timm, G. A. Giusti, and P. J. Tinnin, compilers), Kelseyville and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 102.
Abstract: Recent and current deer research work at Hopland is summarized, including a long-term deer harvest study, buck harvest results, herd composition counts, acorn productivity measurements, and radiotelemetry studies to define deer habitat use and activity. Both hunter and research deer harvests at the field station are summarized from 1978 through 1990. Whole weights of bucks harvest from the station are plotted from 1980 through 1990.


Guy E. Connolly

Wildlife research associate Guy Connolly observes deer as part of long-term herd composition data collection, July 1972

5150. McCullough, Dale R., Floyd W. Weckerly, Pamela I. Garcia, and Rand R. Evett. 1991. **Development of reliable herd composition counts and population estimates for deer in coastal California.** Report to Calif. Dept. Fish and Game, contract FG9521, Jun. 30, 1991, Univ. Calif. Berkeley. 110 pp.
Abstract: To derive reliable direct observation methods, whether evaluated by accuracy or precision, it is necessary to know how deer are using different habitats by season, what their diel activity patterns are, and whether or not alarm behavior may be resulting in their not being observed. Therefore, it is necessary that movements and activity patterns be determined on the same area over the same time period that herd composition counts and line transect observations are being conducted. This allows evaluation of the influence of habitat selection activity cycles, and alarm behavior on probability of deer of different ages and sexes can be observed. It is further desirable that reasonable estimates of population size be obtained by independent methods, so that the use of line transect methods for population estimation can be evaluated for accuracy. This study, conducted at the Hopland Field Station, involved herd composition counts and herd composition data analysis; radiotelemetry and the resulting data regarding habitat use, activity patterns, and alarm behavior; mark-recapture population estimates; and line transect population estimates. We conclude that it is not possible to obtain totally accurate and repeatable results with the methods of herd composition count we utilized. Such counts should be timed by phenological stage rather than by calendar date. A standardized route should be established, run by the same standardized procedures (e.g., start time, direction, speed), and it should be replicated 4-5 times. The cumulative count of deer from replicated surveys should be at least 200. Night spotlight counts are superior to daytime counts. When

interpreting data from herd composition counts, nothing should be concluded from small differences between years, and larger differences should be considered tentative until subsequent years prove to be consistent with the change. The use of moving means is a good way to reach conservative conclusions. In terms of developing population estimates, we believe the line transect method using spotlight data has considerable promise for coastal California. It has shown considerably less variation at Hopland than the mark-recapture method. At minimum, line transect estimates should give useful estimates for determining trend over years.

5151. McCullough, Dale R. 1993. **Variation in black-tailed deer herd composition counts.** J. Wildl. Manage. 57(4):890-897.
Abstract: Herd composition counts are one of the more common methods used to obtain direct measures of deer herd composition that assess herd population status. Thus, I believed it essential to begin to assess shortcomings of herd composition counts. I conducted standardized daylight (early morning) and night spotlight herd composition counts of black-tailed deer (*Odocoileus hemionus columbianus*) weekly on Hopland Field Station in coastal California in 1981-82. Sex and age ratios varied between daylight and spotlight counts, and across seasons. These results suggested that differential behavior by the sex and age classes biased ratios obtained from herd composition counts. Night spotlight counts were less biased than daylight counts. Replicate counts on the same route will improve precision, but variation for the same season between years suggests that biases will not be corrected by replication, and that use of herd composition results for trend also may be unreliable. An independent estimate of population size is recommended to guard against serious errors in herd composition count results

5152. McCullough, Dale R. 1994. **What do herd composition counts tell us?** Wildl. Soc. Bull. 22(2):295-300.
Abstract: I explore the logic of herd composition counts (HCC) to interpret population dynamics. The method assumes that females are a reference class against which proportions of males and offspring are compared. Usually the ratio of males to females is used to interpret the effects of male-biased hunting programs. The proportion of offspring in counts in used as a measure of annual recruitment; i.e., the outcome of birth rate and pre-recruitment death rate. The approach assumes 1) that female recruitment and mortality are relatively stable as compared to male recruitment and mortality; and 2) that female mortality is small relative to offspring mortality. If these assumptions are violated (which may be a particular problem with exploited populations), HCC can be misleading. By themselves, HCC do not estimate population size changes. Sex and age ratios usually are expressed on the basis of 1 or 100 females, illustrating that HCC is an approach analogous to life table analysis and has the same deficiencies for interpretation of population dynamics. An independent estimate of population size is required to safely interpret HCC results. Contingent upon an independent population estimate, I recommend that HCC be used together with management experiments to maximize usefulness of the method.

5153. McCullough, Dale R., Floyd W. Weckerly, Pamela I. Garcia, and Rand R. Evett. 1994. **Sources of inaccuracy in black-tailed deer herd composition counts.** J. Wildl. Manage. 58(2):319-329.
Abstract: Herd composition counts to establish sex and age structure are commonly used to assess population status for deer (*Odocoileus* spp.) and other large ungulates. Such counts are frequently biased, which compromises their usefulness. We evaluated composition counts of black-tailed deer (*O. hemionus columbianus*) for biases by comparing known behavior of a sample of radio-telemetered animals with the outcome of systematic dawn and night spotlight herd composition counts. Three sources of error (differential use of habitats, activity schedules, and deer behavior relative to observers) varied ($P \leq 0.036$) by diel period; only activity schedules did not vary ($P \geq 0.521$) by sex and month. Variation in sources of error was complex because of interactions between monthly and diel periods, month and sex, and diel period and sex. We used stepwise regression to test for the contribution of the 3 sources of error to numbers of deer observed and bias in the sex ratio from herd composition counts. Differential use of habitats accounted for most of the bias with numbers of deer observed, and differential alarm behavior was the only variable that explained a significant amount of variation with sex ratio. Unless herd composition counts are standardized (by route, season, etc.) for deer populations in dense habitats, biases in demographic estimates may fluctuate because errors are not systematic.

5154. McCullough, Dale R. 1996. **Failure of the tooth cementum aging technique with reduced population density of deer.** Wildl. Soc. Bull 24(4):722-724.
Abstract: The molar-layer-cementum technique to age deer was used both for white-tailed deer on the George Reserve, Michigan, and on black-tailed deer at the Hopland R & E Center, California. As densities decreased in the deer populations, annuli became increasingly obscure and disappeared at the lowest density at the George Reserve. It is expected that this effect is seen even in strongly seasonal climates. Not only did annuli become unreliable, but tooth wear also was reduced. Apparently, with reduced population density, deer were able to select high-quality forage with low fiber content that did not cause wear at the same rate as the usual diet.

5155. McCullough, Dale R. 1997. **Breeding by female fawns in black-tailed deer.** Wildl. Soc. Bull. 25(2):296-297.
Abstract: Female fawn breeding is common in white-tailed deer, although it is uncommon in mule deer and their subspecies Columbian black-tailed deer. This paper reports on the collection of female black-tailed deer fawns at Hopland where it was found that 2 of 5 were pregnant. It is theorized that early maturation of female fawns, associated with rapid body growth, was a response to reduced deer density in the experimental population, which had been subjected to adult doe removal over 7 years. While black-tailed deer are recognized to have lower reproductive plasticity than white-tailed deer, it is proposed that black-tailed deer have greater reproductive plasticity than is usually appreciated.

5156. Merenlender, Adina M., Kerry L. Heise, and Colin N. Brooks. 1998. **Effects of subdividing private property on biodiversity in California's north coast oak woodlands.** Trans. West. Sect. Wildl. Soc. 34:9-20.
Abstract: Much of California's biodiversity is found in oak (*Quercus* spp.) woodland vegetation. Residential development is expanding in northwestern California, resulting in a larger number of houses and roads in wooded areas. To examine the effects of this type of habitat fragmentation on biodiversity, 12 low-elevation oak woodland sites with gentle slopes were identified using remote sensing and a geographical information system. These sites were stratified across a gradient of differing lot sizes including large continuous parcels of relatively undisturbed hardwood rangeland in private parcels greater than 122 hectares; ranchettes on 4- to 16-hectare lots; and suburban areas with single-family homes on 0.20- to 1.0-hectare lots. Level of development was shown to have a significant effect on plant and bird species composition, and to be independent of stand structure and tree cover in the surrounding landscape.

5157. Merenlender, Adina M., and Kerry L. Heise. 1999. **Wildlife response to different kinds of residential development.** Oaks 'n' Folks 14(1).
Abstract: Expansion of residential development in wooded areas in California has resulted in land fragmentation and conversion of oak woodlands to housing, roads, and recreational development. A study

was conducted in Sonoma County, CA to quantify effects of development on biodiversity. No significant differences in terms of percent hardwood cover were detected among sites with different degrees of development, when measured by thematic mapper (TM) satellite data. This suggests TM imagery cannot always provide an accurate estimation of fragmentation in oak woodlands. The number of plant, bird, and butterfly species was similar among land-use types, illustrating the difficulties of using species richness to detect changes in ecosystem health. Species composition of bird communities differed among land-use types; the percent of neotropical migrant birds was higher at undeveloped sites than at ranchettes and small suburban lots. Data suggest that smaller property sizes and associated disturbances reduce the diversity and abundance of rarer bird species. The future of California's oak woodlands depends on maintaining large, continuous parcels of privately owned land.


Robert J. Keiffer

HREC neighbor Malcolm King (on ladder) assists in installing wood duck nestbox, Headquarters Lake, Winter 1992

5158. Miller, James E., James Parkhurst, Scott E. Hygnstrom, and Robert M. Timm. 1999. **Panel discussion: wildlife damage conferences: when, where, and why?** Pp. 161-164 *in:* Proc. 9th Nat. Extens. Wildl. Fish. and Aquaculture Conf. (R. M. Timm and S. L. Dann, eds.) Portland, ME, Sept. 29 - Oct. 2. Nat. Res. & Environ. Unit, Coop. State Res. Educ. & Extens. Service, USDA, Washington D.C.
Abstract: From the early 1980s until recently, 3 major wildlife damage management conferences have occurred in North America, each held every 2 years. In recent years, organizers of two of these conferences have encountered increased difficulty in organizing and holding these events. This panel discussion reviews the history of the 3 conferences and describes the emerging role of the Annual Conference of The Wildlife Society in highlighting wildlife damage management topics. It raises questions that need to be addressed concerning the future of such conferences.

5159. Monroe, Michael, and Robert M. Timm. 1975. **Responses of coyotes to odors.** Pp. 13-14 *in:* Proc. Ann. Mtng., Tech. Comm. West. Res. Proj. W-123, "Evaluating Management of Predators in Relation to Domestic Animals," Uvalde, TX, Sept. 4-5.
Abstract: Recent improvement to coyote holding and observation facilities at Hopland are described, as well as coyote research facilities on the UC Davis campus. A standardized method for testing attractancy of odors to coyotes is summarized. Estrous urine was collected from coyotes at Hopland during winter 1975, and this material will be fractioned and tested shortly. A technique for testing the repellency of candidate chemicals has been developed for use with captive coyotes. A food item (dead chicken or rat) is treated with a candidate repellent; after 16 hours in a free-choice test, consumption of the treated item vs. the untreated control is measured by weight.

5160. Müller-Schwarze, Dietland. 1968. **Play deprivation in deer.** Behaviour 31(1-2):144-162.
Abstract: The normal spontaneous play (ludic behavior) in a male and female hand-raised fawn of the black tailed deer (*Odocoileus hemionus columbianus*) is described. The play consists of head jerks, butting, pushing, head shaking, mounting, leaping, running, neck craning and neck twisting, and kicking. Exploratory behavior is independent of locomotor play. Both individuals were repeatedly experimentally deprived of leaping, running and accompanying movements (e.g., kicking). There was no effect on play: all motor patterns occur in their usual frequency after play deprivation. These finding support the hypothesis that play is not due to a species motivation on its own but is closely related to a general readiness to be active, at least for the species in question.

5161. Müller-Schwarze, Dietland. 1969. **Complexity and relative specificity in a mammalian pheromone.** Nature 223(5205):525-526.
Abstract: The tarsal scent was extracted from the hair tuft of tarsal organs collected from male black-tailed deer shot by hunters. The extract was distilled and subjected to gas-liquid chromatography for quantitative analysis and separation of fractions. The fractions were applied to the tarsal tuft of a captive male deer to test the responses of other deer to the scent. Increasing numbers of components in the scent stimulated increasingly stronger responses. Four substances of the male tarsal scent released responses qualitatively identical with the total scent.

5162. Murphy, Edwin L., Robert A. Flath, Dale R. Black, Thomas R. Mon, Roy Teranishi, Robert M. Timm, and Walter E. Howard. 1978. **Isolation, identification, and biological activity assay of chemical fractions from estrus urine attractive to the coyote.** Pp. 66-77 *in:* R. W. Bullard (ed.), Flavor Chemistry of Animal Foods. ACS Symp. Ser. 67, Am. Chem. Soc., Washington, D.C.
Abstract: The efficiency of controlling coyote depredation to livestock could be improved through the availability of a more effective odor attractant. For many years, coyote urine and especially estrous urine has been reported to attract coyotes. Collection, chemical fractionation, bioassay, and chemical component identification of estrous coyote urine are described. Urine was separated into acid, base, and neutral fractions and tested for degree of attractancy by presenting to pairs of captive coyotes. In replicated trials, activities such as licking, chewing, neck-rubbing or rolling, and scent marking were recorded. Gas-liquid chromatography of an acids fraction of estrous urine revealed over 30 major compounds. Nineteen methyl esters of a series of short-chain fatty acids were tentatively identified by use of mass spectral data.

5163. Murphy, Edwin L., Roy Teranishi, Donald S. Balser, and Walter E. Howard. 1979. **Bait posts.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Coeur d'Alene, ID, Aug. 22-23. 4 pp.
Abstract: A "bait post" device for exposing baits to coyotes in the field is described. Essentially, the device consists of a metal rod, which can be driven into the ground, and a clamp that holds a piece of sheepskin treated with a chemical attractant plus a toxicant, sterilant, or other compound. If effective, these devices should be easy to us, pose little environmental hazard, and be relatively

selective for coyotes. Preliminary field tests of such bait posts were conducted at the Hopland Field Station. A variety of animals were attracted to the vicinity of the devices, and most species that visited the sites were not attracted by the scented sheepskin.

5164. Neal, Donald L. 1990. **The effect of predation on deer in the central Sierra Nevada.** Pp. 53-61 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: Two studies, one to determine the direct causes of fawn losses in the North Kings deer herd, and the other to examine mountain lion behavior as it relates to deer, are described. Predation was the largest cause of fawn loss, resulting in the death of 50.6% of all fawns during the first 12 months of life. Mountain lions were the principal predator and were responsible for 49% of the fawn kills. Coyotes, bears, and bobcats took 27%, 22%, and 3%, respectively. Mountain lion density was estimated at 1 per 8 square miles (12.4/100 mi^2). Home ranges averaged 12 square miles for adult females and 135 square miles for adult males. Home range overlap was extensive. Most mountain lions migrated seasonally with the deer, but some remained at low elevation throughout the year on foothill ranches and in the vicinity of rural communities.

5165. Neale, Jennifer C. C., Ben N. Sacks, Michael M. Jaeger, and Dale R. McCullough. 1995. **Comparative use of space and habitat by sympatric bobcats and coyotes in Mendocino County, California (Abstract).** Pp. 90-91 *in:* Abstracts, 2nd Ann. Conf., The Wildlife Soc., Portland, OR, Sept. 12-17.
Abstract: Several studies of sympatric carnivores have demonstrated resource partitioning based on body-size to prey-size ratios and consequent diet and habitat specializations. Few studies have investigated resource partitioning for carnivores of the same size class. We investigated space use patterns of instrumented bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) on and around the Hopland Res. & Ext. Center from June 1994 to July 1995. The study area includes >3,000 ha of oak woodland, pasture, and chaparral slopes. Approximately 6,000 telemetry and visual locations, as well as habitat association and activity information, were obtained on 19 individuals. Preliminary results include 1) spatial overlap between neighboring bobcats and between neighboring bobcats and coyotes was extensive; 2) neighboring coyotes showed little spatial overlap; 3) coyotes exhibited greater home range fidelity than bobcats; 4) bobcats made greater seasonal shifts in home range than did coyotes and consequently occupied larger annual home ranges; 5) bobcats tended to use drainages and areas of heavy cover, such as chaparral slopes and rock outcrops; and 6) coyotes were more variable in their use of different habitats. Seasonal differences in activity, use of overlap areas, and habitat are discussed in light of further analyses.

5166. Neale, J. C. C. 1996. **Comparative resource use by sympatric bobcats and coyotes: food habits, habitat use, activity and spatial relationships.** M.S. Thesis, Univ. Calif. Berkeley. 117 pp.
Abstract: Over 7,000 radio-locations of 13 coyotes (*Canis latrans*) and 12 bobcats (*Lynx rufus*) on the UC's Hopland R & E Center from June 1994 through November 1995 were used to determine habitat use, spatial relationships, and activity patterns. Average adult weights of coyotes (females 10.4 kg, males 11.6 kg) were about twice that of bobcats (females 5.0 kg, males 6.8 kg). Bobcats experienced low mortality, whereas 12 out of 13 coyotes were killed by humans. Density estimates of bobcats and coyotes were identical and relatively high (0.76/km^2). Resident bobcats and coyotes occupied small, stable home ranges. Home ranges of bobcats (9.8 km^2) were significantly larger than coyote home ranges (5.2 km^2). Bobcats and coyotes exhibited frequent and substantial overlap of home ranges and core areas. Bobcats displayed a similarly high level of intraspecific spatial overlap; coyotes, in contrast, occupied mutually exclusive territories. In general, bobcats and coyotes did not display attraction to or avoidance of overlaps with conspecifics or heterospecifics. Bobcats appeared to be most dense at higher elevations where chaparral habitat was most abundant. Temporal segregation was only evident during daytime hours, when bobcats were often active but coyotes were not. Coyotes were consistently nocturnal whereas bobcats were active throughout the 24-hour period. Most available prey were taken by both predators and niche breadth indices were similar throughout the year. Coyotes subsisted primarily on ungulate prey and manzanita berries, whereas bobcats displayed more breadth in terms of frequently-consumed foods, including wood rats, lagomorphs, voles, reptiles, and mice. Coyote consumption of deer was fairly constant all year but sheep became especially important in winter and spring, when lambs were available (constituting up to 45% of the total fresh weight of prey consumed). Indices of niche overlap were generally high in all seasons, but least so during spring and summer; differences were probably attributable to changes in space use and food habits of coyotes related to pup rearing. Resources appeared to be sufficiently abundant to preclude competition between bobcats and coyotes. High prey availability and a mild climate may have permitted high densities of bobcats and coyotes, small home ranges, and extensive overlap in space and time.


Robert J. Keiffer

A field shelter houses radio-telemetry equipment and antenna, used in studies of coyote and bobcat space use as related to predation on livestock, December 1993

5167. Neale, J. C. C., B. N. Sacks, M. M. Jaeger, and Dale R. McCullough. 1996. **Resource use by sympatric bobcats and coyotes in northern California (Abstract).** Pp. 129 *in:* Abstracts, 3rd Ann. Conf., The Wildlife Soc., Cincinnati, OH, Oct. 1-5.
Abstract: Sympatric bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) were studied at the Hopland R & E Center from May 1994 through November 1995. Our primary objective was to evaluate resource partitioning of bobcats and coyotes through examination of their spatial relationships, habitat use, food habits, and diel activity patterns, over 6 consecutive 3-month seasons. Through radiotelemetry (and occasional direct observation) of 12 bobcats and 12 coyotes, we obtained information regarding home range size and fidelity; intra- and interspecific home range and core area spatial overlap; movements; habitat use; and activity patterns. Food habits are currently being investigated by analysis of scats. Results of spatial analyses indicate that bobcats and coyotes occupied relatively small home ranges. Bobcat home range sizes were stable across seasons and larger on average than coyote home ranges; coyote home ranges tended to be smallest during denning and pup-rearing.

Resident coyotes maintained exclusive territories, whereas bobcats displayed extensive spatial overlap with conspecifics. Interspecific spatial overlap was considerable. Preliminary findings regarding habitat use do not provide evidence of partitioning by bobcats and coyotes; both species appear to use areas of heavy cover such as chaparral and riparian thickets for resting sites, hunting grounds, and travel. Overall activity patterns of bobcats and coyote differed in that bobcats were more active during the middle of the day than were coyotes, during all seasons. Both species showed an increase in activity during the middle of the night. Coyotes showed a consistently diel activity pattern across seasons, while bobcat activity was more variable by season and individual. Potential high overlap in resource, use, small home range sizes, and a lack of clear spatial segregation of bobcats and coyotes may be a response to abundant resources at the study site.

5168. Neale, Jennifer C. C., Ben N. Sacks, Michael M. Jaeger, and Dale R. McCullough. 1997. **Overlap and partitioning of space and resources by bobcats and coyotes in northern California (Abstract).** P. 17 *in:* Ann. Conf. West. Sect. Wildl. Soc., San Diego, CA, Feb. 5-8.
Abstract: Sympatric bobcats (*Lynx rufus*) and coyotes (*Canis latrans*) were studied at the Hopland R & E Center from May 1994 through November 1995. Our objective was to evaluate resource use of resident bobcats and coyotes through examination of their spatial relationships, habitat use, food habits, and diel activity patterns. Densities of both species were high. Bobcat home range sizes were stable across seasons and significantly larger on average than coyote home ranges. Coyote home ranges tended to be smallest during denning and pup-rearing. Resident coyotes maintained exclusive territories, whereas bobcats displayed extensive spatial overlap with conspecifics. Interspecific spatial overlap was considerable. Habitat did not appear to be partitioned by species. Bobcats and coyotes were most active at night; however, bobcats were more active during the middle of the day. Both predators consumed the same foods, but coyotes took more large prey whereas bobcats consume a wide variety of small and medium sized prey. Year-round abundance and diversity of resources may have precluded interspecific competition and allowed for small home ranges and high overlap in space and resource use.

5169. Neale, Jennifer C. C., Benjamin N. Sacks, Michael M. Jaeger, and Dale R. McCullough. 1998. **A comparison of bobcat and coyote predation on lambs in north-coastal California.** J. Wildl. Manage. 62(2):700-706.
Abstract: We investigated predation on lambs by bobcats (*Lynx rufus*) relative to coyotes (*Canis latrans*) from June 1994 through November 1995 at Hopland R & E Center (HREC), where both predators occur at equally high densities. Lamb losses during this study were typical for HREC and surrounding ranches and included 64 (5.3% of lambs pastured) confirmed predator kills and 134 (11.1%) missing individuals. Fifty-seven of the predator-killed lambs were attributed to coyotes, whereas none were assigned to bobcats. The proportion of bobcat scats containing sheep remains was small (4.2%), and occurrence did not peak in the lambing season, suggesting that sheep consumed by bobcats were scavenged. Sheep were common in coyote scats (21.4%) and occurred most frequently in scats from the winter-spring lambing season. Coyotes were responsible for all lamb kills in intensively monitored pastures for which predator species could be identified. Use of space by radiocollared bobcats was not noticeably influenced by the presence of lambs. We concluded that bobcats were not important predators of lambs at HREC and not the cause for the relatively large numbers of missing lambs each year.

5170. Neale, J. C. C., and B. N. Sacks. 2001. **Food habits and space use of gray foxes in relation to sympatric coyotes and bobcats.** Can. J. Zool. 79:1794-1800.
Abstract: To investigate interspecific relationships between gray foxes (*Urocyon cinereoargenteus*) and sympatric coyotes (*Canis latrans*) and bobcats (*Lynx rufus*), we quantified occurrence of food items in carnivore scats and used relative abundances of scats on transects to assess space use. Dietary-overlap indices between the two canid species were high during summer and fall ($\bar{x}$ = 0.89) when fruits were prevalent in scats of both species, and were lower during winter and spring ($\bar{x}$ = 0.70) when fruits were less available. Foxes differed most from coyotes in their relatively less frequent ungulate consumption. Fox–bobcat dietary-overlap indices were relatively low in summer and fall ($\bar{x}$ = 0.37) and greater in winter and spring ($\bar{x}$ = 0.74). Foxes differed most from bobcats in their more frequent consumption of fruits and less frequent consumption of lagomorphs. Abundance of fox scats was positively correlated with abundance of coyote scats during both winter–spring ($r = 0.52$, $p = 0.02$) and summer–fall ($r = 0.75$, $p < 0.001$) and with abundance of bobcat scats during winter–spring ($r = 0.59$, $p < 0.01$) and summer–fall ($r = 0.22$, $p > 0.10$). Thus, despite similarities in diet, we found no evidence that gray foxes avoided these larger predators in space.

5171. Neale, J. C. C., and B. N. Sacks. 2001. **Resource utilization and interspecific relations of sympatric bobcats and coyotes.** Oikos 94(2):236-249.
Abstract: We used scat analysis and radiotelemetry to characterize use of foods and habitats by sympatric bobcats and coyotes, and evaluated these in the context of spatial and temporal relationships to assess the potential for, and evidence of, interspecific competition. Bobcats and coyotes exhibited broad and overlapping diets. However, diets of the two predators differed in the relative contributions of small and large prey, with bobcats consuming relatively more rodent and lagomorph biomass and coyotes consuming relatively more ungulate biomass. Consumption among rodent prey species was highly correlated between bobcats and coyotes, indicating no evidence of prey partitioning within this group. Habitat selection by the two predators differed slightly at the landscape scale but not within home ranges. Bobcats and coyotes occupied small, overlapping home ranges, such that the likelihood of interspecific encounters (direct or indirect) was high. Bobcats displayed slight avoidance of overlapping coyote core areas during coyote reproductive seasons (winter and spring), when coyotes are typically most territorial (toward conspecifics), but displayed slight attraction during times of year when coyotes were not engaged in reproductive activities. Relative to coyotes, which were strongly nocturnal, diel activity patterns of bobcats were more diurnal and variable. However, activity patterns were not inversely correlated. Overall, these predators appeared to use resources independently and we found little evidence of negative interactions. Differences in resource use by bobcats and coyotes appeared to relate to fundamental niche differences as opposed to competition-related resource partitioning.

5172. Nesse, Gary E., William M. Longhurst, and Walter E. Howard. 1976. **Predation and the sheep industry in California 1972-1974.** Agric. Exper. Sta. Bull. 1878, Univ. Calif. 63 pp.
Abstract: Surveys of selected sheep ranches were carried out to evaluate the impact of predation on the range sheep industry in California. The objectives were to determine the kinds of predators involved, the numbers of sheep killed or injured, and the economic relationships of predation and predator control. An initial Glenn County, Calif. survey for fiscal year 1973-74 covered 7 sheep ranches. The following year, 66 ranches in Glenn and Colusa counties were surveyed. A third, statewide study involved 140 ranches. Mammal and bird predators together were shown to cause estimated losses of 1,721 sheep valued at $72,319 in 1973-74 in Glenn and Colusa counties (loss rate of 0.7%). Coyotes and dogs

were identified as the primary predators. The total economic loss to the sheep industry in these two counties was estimated to be $208,040. The Glenn county survey data for 1972-73 indicated a 0.5% loss rate for that year; interviews revealed an estimated loss rate of 1.17% for 1971-72 in Glenn County. Statewide, the total loss of sheep to predators during 1973-74 was calculated to be approximately 40,400 head with a direct value of $1,677,775. Including predator control costs and an economic multiplier factor of 2.0, the total impact of sheep predation on the state's economy was about $5,092,000. Coyotes were by far the most important predators of sheep, accounting for 82% of the losses. They were followed by dogs (14.1%), eagles and mountain lions (1.2% each), and bobcats (1%). Bear predation was insignificant.

Guy E. Connolly

The acorn woodpecker is one of more than 200 species of birds that utilize the Center

5173. Noon, Barry R., Patricia N. Manley, and Randolph A. Wilson. 1988. **Silvicultural options in managed oak woodlands to benefit breeding birds.** Final Report to Calif. Dept. of Forestry. Humboldt State Univ., Arcata, CA. 101 pp.

Abstract: Cavity-nesting species compose a significant proportion of the breeding species and the majority of the breeding density. Thus, this guild deserves special consideration in any management decisions. They use a variety of tree species for nest sites; this suggests maintaining a high tree species richness is important. The acorn woodpecker plays a key role in the cavity-nesting guild. This species is the primary source of excavated cavities for the secondary cavity-nesting species. We recommend maintaining large (>55 cm DBH) blue and valley oaks, particularly those with some degree of decadence. Plain titmouse and white-breasted nuthatch nested primarily in natural cavities. These cavities result from injury to the tree followed by diseases which soften the heartwood. Trees with these characteristics should be maintained. Large deciduous oaks (>75 cm DBH) are particularly important as acorn woodpecker granary trees; large valley and blue oaks should be maintained whenever possible. The abundance of the most common breeding species covaried with a large number of vegetative variables; among these were 7 species of hardwoods. The results suggest that a high tree species richness is important to oak woodland birds. The abundance of some of the most common and least common breeding species covaried with tree density, both positively and negatively. To maintain the integrity of the breeding bird community, we recommend maintaining a variety of tree densities. Several species were positively associated with vegetation restricted to the borders of ephemeral streams; these stream corridors should be free of disturbance and grazing should be minimized in such areas. Our data suggest that bird species respond to the diversity in spatial distribution of trees; we recommend that oak woodlands be managed at large spatial scales. Until better data are forthcoming, we recommend 100 ha as the minimum size of a management unit.

5174. O'Bryan, Mary K. 1983. **The outcome of the 1981 Angel Island deer relocation.** M.S. Thesis, Univ. Calif. Berkeley. 87 pp.

Abstract: Controversy over the management of black-tailed deer (*Odocoileus hemionus columbianus*) on Angel Island, San Francisco Bay, Calif., led to a trial of relocation for population control. In 1981, 215 deer were captured and removed from the island at a cost of $87,568. Twelve deer died during capture, holding, and transportation; the remaining 203 were moved successfully to the Mayacamas Mountains near Ukiah, Calif. Deer were monitored for the 12 months following relocation. Most data were derived from a sample of 15 radio-collared deer. Sighting of other relocated deer were documented also (all deer had ear tags). Deer traveled relatively far during the first 3 months following release, covering an area totaling 475 km^2. Thereafter, distances traveled were similar to those of indigenous black-tailed deer. In addition, habitat selection, social behavior, and diet of relocated deer were similar to the native population's. Survival of relocated deer was low; only 2 of the 13 radio-collared deer accounted for throughout the study period survived. Seventeen carcasses of tagged but not collared Angel Island deer were found also. Mortality of relocated deer was attributed to 2 major factors: first, many deer were in poor condition before relocation and probably died shortly after release; second, many deer died from hazards that were not present on Angel Island, i.e., predators (human and other) and vehicles.

Mary K. O'Bryan

Deer captured and removed from Angel Island in San Francisco Bay are released near BLM Cow Mountain Recreation Area, November 1981

5175. O'Bryan, Mary K., and Dale R. McCullough. 1985. **Survival of black-tailed deer following relocation in California.** J. Wildl. Manage. 49(1):115-119.

Abstract: We monitored the survival of 203 Columbian black-tailed deer (*Odocoileus hemionus columbianus*) captured and translocated to the Cow Mountain Recreation Area near, Ukiah, from Angel Island in San Francisco Bay, Calif., in an effort to solve the island over-population of deer. The relocation site in the Mayacamas Mountains was chosen because the resident deer population was considered to be below carrying capacity. During 12 months of monitoring following relocation, only 2 of 15 (15%) radio-collared animals survived; mortality was greatest in the 2 months following release. This compares to 72% annual survival for indigenous deer previously measured in the same location. The initially poor condition of relocated deer contributed to their high mortality rate.

Also, many deer died because they failed to recognize hazards not present on the island environment, specifically predators and automobile traffic. The low survival rate of Angel Island deer during one year following release and reports of similar results for other relocated deer make it difficult to justify relocation on the grounds that it is humane, as claimed by protectionists. Furthermore, relocating large ungulates is expensive. The direct cost of moving these deer was $87,568 which amounted to $431/animal at the time of relocation, or $2,876/deer surviving for one year after release. Relocation is not a satisfactory means of reducing the numbers of deer on overpopulated Angel Island.

5176. Oh, John H., Milton B. Jones, William M. Longhurst, and Guy E. Connolly. 1970. **Deer browsing and rumen microbial fermentation of Douglas fir as affected by fertilization and growth stage.** Forest Sci. 16(1):21-27.
Abstract: The growth rate and crude protein level of Douglas fir seedlings growing on nitrogen deficient soil were increased during the first growing season following fertilization with nitrogen, as were acceptability to deer and in vitro fermentability by deer rumen microbes. The growth rate, crude protein level, and acceptability remained higher during the second growing season after fertilization, although fermentability differences between fertilized and unfertilized trees could no longer be detected. Deer browsing on Douglas fir was limited to new growth throughout the study. New growth was more fermentable and higher in crude protein than older needles, but old needles appeared higher in reducing sugar. Essential oils from Douglas fir had an inhibitory effect upon rumen microbes, and oils from old needles were more inhibitory than those from new growth.

5177. Phillips, Robert L., and Michael W. Fall. 1990. **Control methods and their future application in predation management.** Pp. 81-88 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.) Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: USDA Denver Wildlife Research Center biologists have been working for nearly 50 years in developing and improving tools used in predator control. A wide variety of both lethal and nonlethal control techniques have been investigated. Some new tools have been developed and old tools have been improved. Increased knowledge of coyote ecology and behavior can help to improve the efficiency, efficacy, and selectivity of depredation control programs. Research and development advances in M-44 devices, guarding dogs, traps and other capture devices, denning, baiting techniques, and our understanding of coyote behavior in relation to home range use are described. Studies of golden eagle predation on lambs are briefly summarized.


Robert M. Timm

Western rattlesnake (*Crotalus viridis*), August 1976

5178. Poran, Naomie S., Richard G. Coss, and Eli Benjamini. 1987. **Resistance of California ground squirrels (*Spermophilus beecheyi*) to the venom of the northern Pacific rattlesnake (*Crotalus viridis oreganus*): a study of adaptive variation.** Toxicon 25(7):767-777.
Abstract: Venom resistance was tested in two populations of ground squirrels by injection of 1-40 mg/kg venom doses. One population was obtained from a habitat with a high rattlesnake density; the other populations came from a rattlesnake free habitat. Dramatic differences in the response to venom between these populations were manifested, based on a variety of criteria, such as mortality, necrosis and healing time. Resistance to venom was also examined by LD_{50} tests in groups of mice pre-injected with ground squirrel sera from three rattlesnake-adapted California populations and a non-adapted Arctic population (*Spermophilus parryii*) from snake-free central Alaska. The California ground squirrel sera were 3.3 - 5.3 times more effective in the *in vivo* neutralization of venom than the sera from Arctic ground squirrels. Moreover, the level of protection by the sera as reflected by the LD_{50} values was highly correlated ($P < 0.0005$) with the level of *in vitro* squirrel serum-venom binding as quantified by radioimmunoassay (RIA). A subsequent RIA revealed that binding levels of sera from 14 ground squirrel populations correlated significantly ($P < 0.025$) with local rattlesnake densities; i.e. sera pools from populations sympatric with rattlesnakes exhibited the highest binding, whereas populations living in habitats where rattlesnakes are rare or absent typically exhibited the lowest binding levels, several of which approximated the Arctic control. Taken together, these results demonstrate intraspecific variation that is probably the result of differential natural selection due to northern Pacific rattlesnakes. This intraspecific variation should be taken into consideration when testing for natural resistance in wild-caught species.

5179. Pratt, David W. 1990. **Electric fences for predator control.** Pp. 75-80 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: Three basic types of electric fences are discussed: 1) temporary, portable electric fences; 2) retrofitted fences which consist of electric wires attached to offset insulators mounted on existing fences; and 3) hi-tensile electric fences. The effectiveness of each type for predator control varies depending on the type of predator and predation pressure, terrain, soil moisture, fence design (i.e., post spacing, number of wires, offset spacing, fence height, etc.), and fence maintenance. Temporary, portable electric fences are used primarily to improve grazing management but have limited value for predator control. Retrofitted fences can provide inexpensive, effective protection for sheep against dogs and coyotes. Hi-tensile fences can provide protection from predation by dogs, coyotes, mountain lions, and bears. Materials costs for portable fences, for retrofitting existing sheep fences, and for constructing hi-tensile predator fence are listed. A cost-benefit analysis for a retrofitted fence in Solano County, designed to protect sheep and lambs, is provided.

5180. Pratt, David W. 1991. **Deer fencing design.** Pp. 259-261 *in:* Proc. Columbian Black-Tailed Deer Workshop (R. H. Schmidt, R. M. Timm, G. A. Giusti, and P. J. Tinnin (compilers), Kelseyville and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 102.
Abstract: Practical suggestions for controlling deer damage through construction of both contention and electric fences are summarized. High-tensile electric fencing is described, and references for fence design and component availability are provided.

5181. Pratt, David W. 1992. **Electric fences for predator control.** Pp. 68-73 *in:* Wool Production School (M. R. Dally, J. M. Harper, and P. J. Tinnin, eds.), Ukiah and Hopland, CA. Hopland Field

Station, Univ. Calif., Publ. 103.
Abstract: Design and construction of fences to exclude predators such as coyotes from livestock pastures are reviewed. Temporary portable electric fences are described; these can be of some value in excluding dogs and coyotes in certain situations. Retrofitting of existing fences with electric wires is discussed. An example of a retrofit fence in Solano County, CA is described both in terms of construction technique and cost-effectiveness. High-tensile electric fences can protect livestock from dogs, coyotes, and even mountain lions and bears, given the correct design and construction. An example of high-tensile fence in Napa County, CA to exclude dogs and coyotes is described.

5182. Primus, Thomas M. 2000. **Magnitude of chlorophacinone and diphacinone residues in California rangeland grasses following broadcast application of chlorophacinone and diphacinone fortified steam-rolled oat baits.** Unpublished rept. NWRC QA-542, USDA National Wildlife Research Center, Fort Collins, CO. 208 pp.
Abstract: The study was designed to measure the magnitude of chlorophacinone and diphacinone residues on range grasses following the broadcast application of 0.01% and 0.005% treated steam-rolled oat baits. These anticoagulant toxicants are typically used in this manner for the control of California ground squirrels, and this study was done in support of continued registration of these pesticides. Eighteen test plots measuring 20 × 20 m each were established at Hopland, to which were applied rodenticide baits at 1x and 2x label application rates in July 1998. Range forage samples were collected prior to bait application and at approximately 1, 14, 28, and 90 days post-treatment; these samples were predominantly dry. Residue analyses were conducted at the USDA National Wildlife Research Center, Colorado. Mean residue values for all samples collected after broadcast application were less than the method limit of detection (MLOD). The MLOD for chlorophacinone and diphacinone was 0.051 μg/g and 0.043 μg/g, respectively. Residues in grass samples collected at 141 and 283 days post-application were also less than the MLOD. These samples were predominantly green. The methodology developed for the determination of these two toxicants in range grasses proved to be reliable, efficient, and simple and produced mean recoveries in quality control samples of 86 ± 14% for chlorophacinone (n = 128) and 84 ± 10% for diphacinone (n = 107). The results will be used to determine a tolerance for the consumption of range grasses by livestock.

5183. Sacks, Ben N., Jennifer C. C. Neale, Michael M. Jaeger, and Dale R. McCullough. 1995. **Dynamics of a coyote population in reference to sheep depredation (Abstract).** *In:* Abstracts (Supplement), 2nd Ann. Conf., The Wildlife Soc., Portland, OR, Sept. 12-17.
Abstract: Much is known about how coyotes (*Canis latrans*) use and partition space within populations where they are lightly exploited or unexploited. Although livestock protection has provided the impetus for much of the research conducted on coyotes, most of what is known about coyote populations has come from studies in areas where no livestock exist. We used radio-telemetry to study coyotes from June 1994 to June 1995 at the Hopland Research and Extension Center, a 3,000-ha facility used primarily for animal science research and containing a large flock of research sheep. We found that space use patterns of coyotes at HREC were similar to those found in other places, with breeding adults using mutually exclusive territories throughout the year and young and senescent individuals often roaming between territories. Breeding adults that held territories containing lambs were responsible for most of the depredations. Breeding adults were only vulnerable to control efforts during the pup-rearing season. Nonbreeding coyotes made up the bulk of removals during the rest of the year. We suggest that the timing of lambing and the focus of removal efforts in space and time are critical considerations in lessening sheep depredations.

5184. Sacks, Ben N., Jennifer C. C. Neale, Michael M. Jaeger, and Dale R. McCullough. 1995. **Fine- and coarse-scale space use patterns by coyotes in Mendocino County, California, with an "i" towards "y" (Abstract).** P. 116 *in:* Abstracts, 2nd Ann. Conf., The Wildlife Soc., Portland, OR, Sept. 12-17.
Abstract: We used radiotelemetry to examine coyotes' (*Canis latrans*) use of space over several time scales with reference to other individuals, landscape features, predator control devices, and sheep. Seventeen coyotes were captured, radiocollared, and simultaneously tracked using 3 fixed stations from April 1993 to December 1994. Continuous radiotracking with hand-held antennas at close range (500-800m) began in January 1995 and will continue until July 1995. Preliminary results from fixed-station telemetry suggest that other coyotes are the primary factor influencing large-scale movements (home range shifts) and that heavy concentrations of M-44s, traps, and snares have no apparent effect on space use. Results from fine-scale telemetry are expected to illuminate the relative importance of landscape features and sheep in the daily movements of coyotes.


Karen Blejwas

UC Berkeley graduate student Ben Sacks demonstrates trap-setting techniques to visiting group of Berkeley High School biology students, Summer 1994

5185. Sacks, Benjamin N. 1996. **Ecology and behavior of coyotes in relation to depredation and control on a California sheep ranch.** M.S. Thesis, Univ. Calif. Berkeley. 223 pp.
Abstract: I studied a coyote (*Canis latrans*) population in a sheep ranching environment at the Hopland Res. & Ext. Center (HREC). Objectives were to obtain basic ecological and behavioral information on coyotes and to describe relationships among human exploitation/control, coyote biology, and sheep depredation. Information was obtained from radiotelemetry of 16 coyotes, post-mortem examinations of 50 coyotes (including some of those collared) removed by Animal Damage Control and shepherds 1992-1995, and examination of historical data. During the first year of the study (1993-94), no effort was made to remove coyotes. During the second year (1994-95), control was heavy (34 coyotes removed from the 21.7 km^2 study area). Fifty-eight percent of 50 coyotes were <1 year old; another 18% were <2 years old, and 24% were 2 to 4 years old. Adult males were heavier than adult females, averaging 12.3 kg (SD = 1.7, *n* = 17) and 9.8 kg (SD = 1.2, *n* = 21), respectively. Heartworm (*Dirofilaria immitis*) was found in adult and yearling coyotes with increasing frequency from 0% in 1992 and 1993 to 100% by 1995. The average maximum litter size (estimated from uterine scars) was 7.2 (range 4-9, *n* = 5). Territories of resident coyotes were small (average annual 95% minimum convex polygon

(MCP): 5.0 km^2, range 3.0-7.4 km^2) and mutually exclusive. Transients disproportionately used the space among, and on the peripheries of, territories. Coyote density was estimated for 3 semiannual periods and ranged from a pre-whelping density of 0.5 coyotes per km^2 to post-whelping densities of 0.6 (1994) and 0.7 (1995). Territories often included non-breeding associates in addition to the breeding pair. During the year of no control (1993-94), when tracking was from fixed stations, coyotes were primarily crepuscular. The following year (1994-95), when control was heavy and tracking was done with hand-held antennas at close range, coyotes were primarily nocturnal. The combination of human threat and increased human activity may have caused the difference in activity patterns between the 2 years. Whelping occurred over a 1-month span from mid-March to mid-April. Subterranean dens near water were used initially, and pups were later moved to above ground rendezvous sites. Pups typically were relocated every 2 to 3 weeks, often as a result of human disturbance. The loss of a mate apparently caused females to spend a greater proportion of time away from the den, probably hunting, because they had become the sole provider of food to their pups. This increased activity seemed to compromise the mothers' health and increase their vulnerability to capture. Where sheep were not available, manzanita berries were an important food source in summer and fall, especially in territories at higher elevations (where manzanita is most abundant). Lagomorphs and rodents were consumed most during winter and spring, when manzanita was less available. Deer was consumed heavily during all times of the year, especially in winter and spring.

Radiotelemetry was used to determine that breeding adults were killing most of the sheep at HREC, and that one pair, which had the highest access to lambs (and total sheep), was responsible for most of the depredations. Another pair, that had only adult ewes available, tended not to kill sheep but did scavenge sheep. Availability of sheep did not appear to be sufficient to explain the number of sheep killed within territories. Wild prey abundance and length of residence in a territory probably influenced the level of sheep depredation by pairs. Pairs new to a territory may not kill sheep as readily as longer established pairs, especially when wild prey is abundant. The annual sheep kill over 21 years at HREC was compared to vole abundance, and annual rainfall and plant productivity (both assumed to be correlated with overall wild prey abundance). Vole abundance was not significantly correlated with sheep kills. Inverse relationships were found between both rainfall and plant productivity (which were highly correlated with each other) and sheep kills (r = -0.52, -0.53, respectively, $P < 0.05$ each). This suggests that in years when small mammal abundance (but not necessarily vole abundance) was high, coyotes preyed on sheep less frequently. However, the monthly numbers of sheep killed by coyotes within each year appeared to be primarily a function of the number of lambs available.

Success of techniques used to capture/kill coyotes varied by coyote age class. M-44s were responsible for the most coyote removals but were ineffective at removing adults. Opportunistic shooting, snares, and leghold traps appeared to be least selective. Calling-and-shooting near the den was very effective on breeding adults and their pups; breeding adults were much less vulnerable outside of the pup-rearing period. When the breeding pair was removed from a territory, 3 coyotes (2 breeders from different neighboring territories and one transient adult) moved into the vacancy and were captured in leghold traps. Their captures were probably facilitated by their unfamiliarity with the area.

Because it seems that only a few coyotes cause most of the damage at HREC during any given year, this management problem is best approached on an individual, rather than population, scale. Breeding adults (which are responsible for most sheep depredations) often may be removed too early in the year to prevent new pairs from moving in before the lambing season. The Livestock Protection Collar may be an effective way to selectively remove sheep-killing coyotes immediately prior to lambing when most other methods are ineffective on breeding adults. Fall and winter removals of juvenile coyotes may be counterproductive by reducing potential food competition among remaining coyotes, thereby promoting younger breeders and larger litters.

5186. Sacks, B. N., J. C. C. Neale, M. M. Jaeger, and D. R. McCullough. 1996. **Ecology of coyotes in a sheep ranching environment (Abstract).** *In:* Abstracts, 3rd Ann. Conf., The Wildlife Soc., Cincinnati, OH, Oct. 1-5.
Abstract: Coyotes (*Canis latrans*) were studied at Hopland R & E Center (HREC) from 1993 through 1995. Information was obtained through radio tracking of 16 coyotes and necropsies of 50 coyotes removed by Animal Damage Control (ADC) and hunters. No coyote control occurred during the first study year but control was intensive during the second. Annual survival rates were: 0.69 (± 0.27) for the first year, and 0.31 (± 0.22) for the second year. Twenty-nine (58%) of the coyotes captured were less than 1 year old; another 8 (18%) were less than 2 years old, and the remaining 11 (24%) were 2 to 4 years old. Prewhelping density was estimated at 0.5 coyotes/km^2. Average annual 95% minimum convex polygon (MCP) home range was 5.0 km^2 (range of 3.0-7.4 km^2) for resident coyotes. Territories of breeding adults were mutually exclusive. Nonbreeding coyotes varied in their space use, falling on a continuum ranging from resident (probably in natal territories) to transient. When transient or out of their natal territory, nonbreeders avoided breeding coyote territories. Nonbreeders also seemed to avoid breeders temporally by being active during the middle of the day when breeders were least active. Resident coyotes were crepuscular when no control occurred (1993-94), but nocturnal when control was intensive (1994-95). During winter 1995, a pair situated on the central part of HREC, where 1) human activity was high, 2) sheep were abundant, and 3) vegetative cover was limited, had movements clustered in space and time around isolated patches of cover; this pairs diet included much sheep and little deer. In contrast, a pair whose territory was located on the periphery of HREC during the same period, where 1) human activity was relatively low, 2) sheep were scarce (but nearby), and 3) vegetative cover was abundant, had movements that were more uniformly distributed over space and time; this pair's diet included little or no sheep and much deer. During pup-rearing, breeders used space similarly regardless of human activity within their territory, centering their activity around den or rendezvous sites. Pup-rearing was a cooperative effort between the breeding male and female of a pair. Mothers that were widowed during pup-rearing spent more time away from dens, were in poorer nutritional condition, and were more vulnerable to control, than mothers with living mates. Health of pups did not seem to be diminished by the death of their father.

5187. Sacks, Benjamin N., Jennifer C. C. Neale, Michael M. Jaeger, and Dale R. McCullough. 1997. **Ecology of coyotes in relation to depredation and control on a California sheep ranch (Abstract).** P. 25 *in:* Abstracts, Ann. Conf., West. Sect. Wildl. Soc., San Diego, CA, Feb. 5-8.
Abstract: Coyotes (*Canis latrans*) were studied at Hopland R & E Center (HREC), a working sheep ranch, from 1993 through 1995. Information was obtained through radio tracking of 16 coyotes and necropsies of 50 coyotes removed by Animal Damage Control (ADC) and others. Territories of breeding adults were mutually exclusive. Nonbreeding coyotes ranged from resident to transient. When transient, nonbreeders avoided breeding coyote territories. Resident coyotes were crepuscular when no control occurred (1993-94), but nocturnal when control was intensive (1994-95). During the non-pup-rearing period, coyotes living in areas of high human activity had movements clustered in space and time, whereas those in areas of lower human activity had movements that were more uniformly distributed in space and time. During pup-rearing, breeders used space similarly to one another, regardless of human

disturbance, centering activity around dens or rendezvous sites. Breeding adults with territories containing lambs were responsible for most depredations. Breeding adults were only vulnerable to control efforts during the pup-rearing season. Young, non-breeding coyotes make up the bulk of removals during the rest of the year. We suggest that sheep depredation is a function of foraging behavior of individual coyotes and not coyote population dynamics.

5188. Sacks, Benjamin N., Karen M. Blejwas, and Michael M. Jaeger. 1999. **Relative vulnerability of coyotes to removal methods on a northern California ranch.** J. Wildl. Manage. 63(3):939-949.
Abstract: Evidence suggests that predation on domestic sheep by coyotes (*Canis latrans*) is caused primarily by breeding pairs with territories overlapping sheep. Accordingly, we investigated vulnerability of coyotes to removal methods relative to factors associated with reproduction and territoriality. We collected live and lethal coyote capture data during April 1993 - February 1998 on a north-coastal California sheep ranch. Routine coyote removal was conducted in response to sheep depredation before and during (part of) the study. Younger (nonbreeding) coyotes generally were more vulnerable to capture than older (potentially breeding) individuals, although age bias varied among removal methods. Recaptures of radiocollared coyotes in foothold traps and snares indicated a bias toward progressively younger individuals (juv > yearling > ad; P = 0.002). Proportionally more juvenile and yearling coyotes were removed by M-44s (sodium cyanide ejectors) than by traps and snares (P = 0.016). We found no difference between traps and snares in the ages of coyotes taken (P = 0.50). Vulnerability of younger coyotes was likely elevated by lack of experience and more time spent in unfamiliar areas where they were least able to avoid capture devices. Coyotes were caught more often than expected outside of core areas of their territories with both traps (P = 0.001) and snares (P = 0.02). Older coyotes were most vulnerable in spring and summer when rearing pups, after most depredation occurred. Radiocollared breeders (P = 0.012) and uncollared coyotes of breeding age (P = 0.052) were captured less often during the non-pup-rearing period than the pup-rearing period. These results suggest conventional control in northern California is poorly suited to the segment of the coyote population killing the most sheep, particularly during the time of year when most sheep depredation occurs. Efficacy of control methods might be improved by conservative use of conventional devices to minimize learned avoidance by coyotes, and by greater reliance on methods such as Livestock Protection Collars that are specific to depredating individuals throughout the year.

5189. Sacks, Benjamin N., Michael M. Jaeger, Jennifer C. C. Neale, and Dale R. McCullough. 1999. **Territoriality and breeding status of coyotes relative to sheep predation.** J. Wildl. Manage. 63(2):593-605.
Abstract: Coyote (*Canis latrans*) depredation is a chronic problem for sheep producers in the western United States. Due to increasingly localized control efforts, behavior of individual coyotes in sheep-ranching environments is becoming a more important consideration. We radiotracked 14 coyotes on a year-round sheep-ranching facility in north-coastal California during September 1993 - December 1995. Breeding coyote pairs used mutually exclusive territories (maximum overlap between 90% adaptive kernel home ranges = 4%). Non-breeding coyotes were transient or varied in their degree of fidelity to putative natal territories but generally avoided cores of nonnatal territories. Breeding coyotes whose territories contained sheep were the principal predators of sheep. In the 1994 lambing period (1 Jan - 31 May), radiotelemetry indicated that 1 breeding male was responsible for 71% of 65 kills. In the 1995 lambing period, 4 breeding pairs were strongly implicated in 92% of 48 kills and were suspected of 85% of 26 additional kills; nonbreeders were not associated with sheep depredation. Depredation was reduced only when territorial breeders known to kill sheep were removed. These results suggest the need for management to target breeding adults in the immediate vicinity of depredation. Efforts to remove individuals >1 territory-width away from problem sites are unlikely to reduce depredation and may exacerbate the problem by creating vacancies for new breeders that might kill sheep.

5190. Salmon, Terrell P., and Rex E. Marsh. 1989. **The influence of burrow destruction on recolonization by ground squirrels.** Progress Report submitted to Statewide UC IPM Project, FY 1989-90, Dec. 20, 1989. Univ. Calif. Davis. 10 pp.
Abstract: The studies in progress are testing the effect of physically disturbing the entrances to ground squirrel burrow systems on recolonization (reinvasion) rate following ground squirrel population removal. The results show that ripped burrows have lower recolonization rates than non-ripped (control) burrows at all experimental sites. Previous work had indicated that ripping the entrances to California ground squirrel (*Spermophilus beecheyi*) burrows on small blocks reduced recolonization when other alternative vacant burrows were available nearby. These results were confirmed in this series of tests with the Belding ground squirrel (*S. beldingi*), another important pest species in California agriculture. Ripping the entrances to Belding ground squirrel burrow systems in an alfalfa field was more effective than rototilling (6% versus 29% of the systems recolonized, respectively, versus 50% of the control). Tests of ripping as the sole treatment over large blocks are in progress. Preliminary results from the UC Hopland Field Station show that non-ripped burrows had a recolonization rate 3.5 times higher than ripped burrows. Practical and economic aspects are now being evaluated. Before considering implementation of this method as a part of an integrated pest management program, the existing plots have to be monitored over a long period of time and this cultural method evaluated as to its feasibility. A decrease in the reliance on rodenticides is expected if a significant reduction in reinvasion rates can be maintained.

5191. Schmidt, Robert H. 1987. **Book Review: A review of Wildlife Management.** J. Range Manage. 40(1):95.
Abstract: This new volume by J. M. Peek is found to be valuable as a text for both undergraduate and graduate students, and as a reference book for wildlife professionals. It provides a foundation upon which more current, and shifting, attitudes and management practices can be examined and evaluated. Range managers and foresters with an interest in wildlife management will find it especially useful.

5192. Schmidt, Robert H. 1987. **Characteristics of fund-raising solicitations by environmental and animal rights organizations.** Trans. West. Sect. Wildl. Soc. 23:54-57.
Abstract: This paper analyzes a full year of direct mail fund-raising solicitations received by the author in 1986. Ninety-nine solicitations were received from 33 organizations. The average minimum donation requested was $15.33. Most organizations were headquartered east of the Mississippi River. Wildlife and environment issues were the main theme of 75 of the solicitations, with animal rights and animal welfare the dominant theme of 21. Marine mammals, animal suffering, endangered wildlife, and environmental protection were issues emphasized.

5193. Schmidt, Robert H. 1987. **A worksheet for authorship of scientific articles.** Bull. Ecological Soc. Amer. 68(1):8-10.
Abstract: This paper details a method for assisting in 1) deciding who is to be listed as an author on a paper, and 2) the ordinal ranking of the authors listed on a paper.

5194. Schmidt, Robert H. 1987. **Historical records of gray wolves in California.** Wolf! 5(2):31-35.
Abstract: Gray wolves probably were never abundant in California,

although reports consistently show they were present historically in the Sierra Nevada, especially in the northern portion, and in the southeastern portion of the state. Circumstantial evidence suggests that gray wolves were also present in parts of the Central Valley and Coastal Range. Fossil evidence and historical sightings are summarized. The writings of early naturalists reporting observations of wolves within the state are excerpted. Available information suggests that gray wolf distribution became increasingly limited during the late 1800s and may have disappeared entirely by the 1940s, with the last individuals having been seen in the Sierra Nevada range. Gray wolves probably occurred in the Central Valley and Coastal Range until the early 1800s, although their numbers in these locations may have been small. Traps, guns, and poisons (strychnine) may have been extremely effective at reducing wolf numbers, especially in the open grasslands and oak woodlands of the livestock producing regions.

5195. Schmidt, Robert H. 1987. **Results of a membership questionnaire for the Western Section of the Wildlife Society.** Trans. West. Sect. Wildl. Soc. 23:91-96.
Abstract: This paper summarizes the results of a questionnaire sent to all members of the Western Section of the Wildlife Society (TWS) in 1985. One hundred and seventy-four (64%) of the members returned their questionnaire forms for analysis. Members indicated a concern for increased Section involvement in conservation activities and conservation education. Demographics, education, employment status, concerns about professionalism, certification, and continuing wildlife education are included in the analysis.

5196. Schmidt, Robert H. 1987. **Taking the great animal crusades over the top.** Rangelands 9(3):132-133.
Abstract: The Animal Protection Institute, a major animal welfare group, held a conference in 1986. Issues covered during the three-day conference included egg production using hens in battery cages, veal production, the trade in primates, project WILD, hunting and trapping on national wildlife refuges, the Dairy Termination Program, trapping in general, marine mammals, hunting in general, animal rights, pesticides, and drugged racehorses. This article suggests that all animal users need to acquaint themselves with the philosophies and concerns of the animal rights and animal welfare organizations.

5197. Schmidt, Robert H. 1987. **Wildlife impacts on reproduction and mortality of oaks in California: is there a role for animal damage control?** Pp. 37-39 *in:* Proc. Symp. Anim. Damage Manage. in Pac. Northwest Forests (R. L. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Breuer, eds.), Spokane, WA, Mar. 25-27. Cooperative Extension, Washington State Univ.
Abstract: Recent concerns about the effects of subdivisions, range improvement practices, firewood cutting, and timber harvesting operations on the long-term dynamics of oak distribution in California have resulted in the identification of impacts that wildlife have on acorn and seedling mortality and the reproduction and regeneration of mature stands. Principles and techniques from animal damage control may be able to mitigate these impacts, but economics and practicality will limit options.

5198. Schmidt, Robert H., and William D. Tietje. 1987. **Coordinating wildlife management with hardwood conservation: the extension approach.** Trans. West. Sect. Wildl. Soc. 23:33-35.
Abstract: The conservation of the hardwood resource in California is a major concern. Hardwoods, especially oaks (*Quercus* spp.), are an important habitat component for many wildlife species. In recent years demands for lumber and wood products, firewood, urban development, and forage enhancement programs for livestock have resulted in decreased acreage of hardwoods. Regeneration of some oak species has been poor. To address these issues, the University of California, Division of Agriculture and Natural Resources, has established a new hardwoods range program. This paper reviews the program and describes its potential impact on wildlife in California.


Guy E. Connolly
Fish & Game biologist Charles Moon (front) and an assistant release wild turkeys at Hopland, September 1972

5199. Schmidt, Robert H. 1988. **Book Review: Building Models for Conservation and Wildlife Management.** J. Range Manage. 41(4):360.
Abstract: The book's authors, A. M. Starfield and A. L. Bleloch, suggest the use of models as important decision-making aids in conservation and wildlife management, noting that the very process of building a model highlights the aspects of an ecological system which are helpful at the decision- making level. Topics covered include simple and complex single-species models.

5200. Schmidt, Robert H. 1989. **Animal welfare and wildlife management.** Trans. N. Am. Wildl. Nat. Res. Conf. 54:468-474.
Abstract: The "human dimension" in natural resource management is evolving rapidly. In particular, animal welfare issues, as they relate to activities, techniques and programs of wildlife biologists are receiving more attention then they have in the past. Examples include leghold traps, vertebrate pest control, lead versus steel shot, mountain lion hunting and wild horse management. Attention is being focused on university and agency animal use and care committees, and the appropriateness of all types of research which may cause pain and distress to animals. Currently, wildlife biologists, like many professionals in the agricultural and biomedical communities, are very sensitive to criticism regarding animal welfare issues. This paper explores the philosophical and ethical consequences of what wildlife biologists do for a living. Are we the saviors of wildlife or ruthless sadists? How can wildlife biologists survive the next decade with their sanity, respect and professionalism intact?

5201. Schmidt, Robert H. 1989. **Effects of animal welfare philosophy on wildlife damage control.** Pp. 24-26 *in:* Proc. 9th Gt. Plains Wildl. Damage Control Wkshp. (A. J. Bjugstad, D. W. Uresk , and R. H. Hamre, tech. coords.), Fort Collins, CO, Apr. 17-20. U.S. For. Serv., Rocky Mt. For. Range Exp. Stn., Gen. Tech. Rep. RM-171.
Abstract: Wildlife damage prevention and control activities are often criticized when they involve the deaths of wild animals. However, just as the nuclear industry has failed to convince the majority of the public that its industry is safe, education will fail to convince the public that all wildlife damage control techniques are humane. Animal welfare-related legislation, university rules on the use of wild animals for research, and litigation are changing the working

environment of our profession. This paper reviews aspects of the animal welfare movement as they affect the wildlife damage prevention and control profession and discusses future strategies for living with it.

5202. Schmidt, Robert H. 1989. **Vertebrate pest control and animal welfare.** Pp. 63-68 *in:* K. A. Fagerstone and R. D. Curnow (eds.), Vertebrate Pest Control and Management Materials. STP 1055, Am. Soc. for Testing and Materials, Philadelphia, PA.
Abstract: More than other types of wildlife management practices, vertebrate pest control activities elicit strong responses from the animal welfare community. The vertebrate pest control profession needs to become more aware of the concerns of this group, and sincere attempts must be made to incorporate their concerns in research and management practices. To assist this task, recommendations for decision making to address animal welfare concerns for vertebrate pest control activities are given, along with a set of criteria for developing humane toxicants.

5203. Schmidt, Robert H. 1990. **Animal welfare considerations in predator management.** Pp. 33-37 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Hopland and Ukiah, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: The author draws a clear distinction between "animal rights" and "animal welfare." Animal welfare concerns need to be incorporated in decisions regarding predator management in California, including current predator management and predation control practices. The alternative is a continuing erosion of the public's confidence in professional wildlife management.

5204. Schmidt, Robert H. 1990. **Book Review: Quantitative Aspects of the Ecology of Biological Invasions.** J. Range Manage. 43(3):278.
Abstract: This 1987 volume, edited by H. Kornberg and M. H. Williamson, is the proceedings of a 1986 Royal Society meeting which dealt with introductions of non-native trees, diseases, fish, birds, insects, weeds, and mammals. Three major questions are investigated: 1) what factors determine whether a species will become an invader; 2) what properties determine whether an ecological system will be prone to, or resistant to, invasion; and 3) how should management systems be developed to address invading species. Emphasis is on British flora and fauna.

5205. Schmidt, Robert H. 1990. **Why do we debate animal rights?** Wildl. Soc. Bull. 18(4):459-461.
Abstract: A distinction between animal welfare and animal rights is emphasized: followers of the animal rights movement believe animals have rights equal or similar to those of humans, while the animal welfare movement is primarily concerned about reducing pain and suffering in animals. Wildlife biologists and managers should focus attention on meeting animal welfare concerns, as they are held by a majority of persons in the U.S. It is in the best interests of biologists to put time and energies into dealing with legitimate animal welfare issues, and to integrate such concerns into current and future management plans.

5206. Schmidt, Robert H., Robert M. Timm, and Gregory A. Giusti. 1991. **Columbian black-tailed deer: a resource in transition or in jeopardy?** Proc. Columbian Black-Tailed Deer Workshop Publ. 102:1-3.
Abstract: This introduction to a Proceedings raises questions and concerns resulting from an apparent decline in the harvest of Columbian black-tailed deer in Lake County, California, and elsewhere since the early 1960s. Deer harvest data for Lake County, Region III, and the state are presented in two figures. Questions raised include reasons for the decline in harvest, relationships between deer numbers and the habitat's carrying capacity, and a changing social and political environment.

Guy Connolly obtains live weight of captured doe, July 1963

5207. Schmidt, Robert H. 1991. **Gray wolves in California: their presence and absence.** Calif. Fish and Game 77(2):79-85.
Abstract: Gray wolves, *Canis lupus*, probably occurred in the Central Valley, the western slope of the Sierra Nevada foothills and mountains, and in the coast ranges of California until the early 1800s, although their population size is unknown and may have been small. Fossil records and early recorded observations attest to the presence of gray wolves in these areas. In addition, the proximity of other wolf populations east of the Sierra Nevada and north of California, the extensive historical range of gray wolves worldwide, and the presence of large ungulates as potential prey provide indirect evidence that wolves inhabited this region. If gray wolves were more abundant and widely distributed 300 years ago, it is possible that there were fewer coyotes, *Canis latrans*, than at present. Community-level dynamics between canids (including the San Joaquin kit fox, *Vulpes macrotis*) may have been much different than they are today.

5208. Schmidt, Robert H., and Robert M. Timm. 1991. **Vertebrate impacts on oak regeneration in California: a review of management options.** Pp. 134-144 *in:* Proc. 10th Gt. Plains Wildl. Damage Control Wkshp. (S. E. Hygnstrom, R. M. Case, and R. J. Johnson, eds.), Lincoln, NE, Apr. 15-18. Gt. Plains Agricultural Council Publ. 137.
Abstract: Concern exists about the ability of certain oak woodland stands in California to replace themselves in today's environment. While the actual mechanisms resulting in failure of valley oak, blue oak, and Englemann oak to regenerate adequately are unknown, a number of factors acting in concert or alone are presumed responsible. These include rodent, bird, pig (*Sus scrofa*), and deer (*Odocoileus hemionus*) predation on acorns; rodent, rabbit (*Lepus* and *Sylvilagus* spp.), and deer browsing on seedlings; and livestock consuming acorns and seedlings. Acorn and seedling protection strategies are discussed.

5209. Schmidt, Robert H., Robert M. Timm, Gregory A. Giusti, and P. J. Tinnin (Editors). 1991. **Proceedings, Columbian Black-tailed Deer Workshop.** Publ. 102. Hopland Field Station, Univ. Calif. 274 pp.
Abstract: The California population of black-tailed deer is adjusting to a new equilibrium. The presentations made during this workshop review many, but not all, of the various factors affecting this new equilibrium. There may be opportunities to manage habitats in the near future which will allow this equilibrium to be changed again. However, perceptions regarding the role of deer as a consumable versus aesthetic resource are also changing. Human uses for deer are

also finding a new equilibrium. We do not expect the management of Columbian black-tailed deer to be static into the 21st Century.

Guy E. Connolly

Deer browsing on young Douglas fir trees can reduce the success of reforestation efforts

5210. Schmidt, Robert H., Dale L. Brooks, and Terrell P. Salmon. 1992. **Social, political, legal, and ethical aspects of animal damage management in forestry.** Pp. 395-404 *in:* H. C. Black (tech. ed.), Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests. Gen. Tech. Rep. PNW-GTR-287, USDA For. Serv., Pac. Northwest Res. Sta.
Abstract: Animal damage management, as practiced in today's forests, is increasingly affected by social, political, legal, and ethical environment in the United States. These elements effect the materials utilized to manage animal damage, the silvicultural systems used to manipulate forest vegetation and thus wildlife habitat, and the human effort required to initiate and complete damage reduction programs. Failure to incorporate societal values in decision making processes will lead to increased risk of program modification or failure.

5211. Schultz, Thomas H., Robert A. Flath, Donald J. Stern, T. Richard Mon, Roy Teranishi, Sheila M. Kruse, Barbara A. Butler, and Walter E. Howard. 1988. **Coyote estrous urine volatiles.** J. Chem. Ecol. 14(2):701-712.
Abstract: Samples of female coyote urine were taken once or twice each week during winter and spring for two years. Headspace analysis was employed with Tenax GC trapping and GC-MS. Tenax trapping was started in less than 1 hour after sampling, and mild conditions were used to minimize losses of highly volatile and labile compounds. Thirty-four compounds were identified. They include sulfur compounds, aldehydes and ketones, hydrocarbons, and one alcohol. The principle constituent is methyl 3-methylbut-3-enyl sulfide, which usually comprised 50% or more of the total volatiles observed. The concentration of many constituents varied widely. This appeared to be quasiperiodic for five of the constituents, with a period of a few weeks, and with pronounced maxima at the peak of estrus. Apparently these compounds are 3-methyltetrahydrothiophene, methyl 3-methylbutyl sulfide, octanal, dodecanal, and *bis*(3-methylbut-3-enyl) disulfide. One or more of these compounds may have a pheromonal activity in coyote relationships.

5212. Schultz, Vincent, and William M. Longhurst. 1963. **Accumulation of strontium-90 in yearling Columbian blacktailed deer, 1950-60.** Pp. 73-76 *in:* 1st Natl. Symp. on Radioecology (V. Schultz and A. W. Klement Jr., eds.), Fort Collins, CO, Sept. 10-15, 1961. Reinhold Publ. Corp., New York, NY.
Abstract: Jawbones from 49 yearling deer collected on the Hopland Field Station were analyzed for calcium and for strontium-90. It is to be expected that ^{90}Sr concentrations are a function of seasonal food habits, age, and home range. From the data, it is obvious that ^{90}Sr concentrations in deer have increased during the study period. Although further sampling is needed, it appears that the peak of accumulation following cessation of atmospheric atomic testing has been reached.

5213. Scrivner, Jerry H., Walter E. Howard, and Roy Teranishi. 1984. **Aldehyde volatiles for use as coyote attractants.** Pp. 157-160 *in:* Proc. 11th Vertebr. Pest Conf. (D. O. Clark, ed.), Sacramento, CA, Mar. 6-8.
Abstract: This study was designed to evaluate the attractiveness of eight aldehyde volatiles (octanal, nonanal, decanal, undecanal, dodecanal, tridecanal, tetradecanal, and hexadecanal) found in sheep liver extract and coyote (*Canis latrans*) estrous urine to determine their potential for use as odor attractants in predator control. The odors were presented to captive coyotes at Hopland Field Station and the length of time coyotes responded to the odors recorded. Octanal, nonanal, decanal, and undecanal all elicited as much sniffing and rub-rolling as did a known coyote attractant, trimethylammonium decanoate (TMAD). Generally male and female coyotes were equally attracted to the odors; however, nonanal was preferred by males in summer and females in winter. In comparison to TMAD, some aldehydes were effective in eliciting sniffing and rub-rolling but ineffective in eliciting lick-chewing and biting. Thus, the aldehydes are probably best suited as odor attractants for use with capture devices such as the steel trap, and least suited for use with toxicant-delivery systems such as the M-44.

5214. Scrivner, Jerry H., Walter E. Howard, and Roy Teranishi. 1984. **Coyote behavior in response to five chemical attractants (Abstract).** P. 63 *in:* Proc. 64th Ann. Mtng. Am. Soc. Mammalogy, Arcata, CA, Jun. 24-28.
Abstract: Beginning in 1972, a multidisciplinary team comprised of researchers from the University of California and USDA initiated chemical and behavioral studies from coyotes (*Canis latrans*). Such information not only increases the understanding of coyote behavior, but also has management implications since the use of odorous lures are commonly used in predator control. This study described the results of one test wherein 10 captive coyotes (sexes equal) were exposed to five odors and a control. The attractants were presented to each coyote in randomized pairs in 60 trials. A total of two exposures per coyote was obtained for each attractant in 120 odor presentations. Preference (based on average time coyotes spent at the odors) for the five odors was as follows: trimethylammonium decanoate (TMAD)/sulfide combination > TMAD/sulfide/dodecanal combination > TMAD/sulfide/cheese-smelling additive combination > synthetic calf feces > TMAD. (Compounds related to TMAD and dodecanal are found in estrous-coyote urine.) The results are discussed in terms of specific behaviors elicited by the odors and how seasonality influences coyote-response time.

5215. Scrivner, Jerry H., Walter E. Howard, Alfred H. Murphy, and John R. Hays. 1985. **Sheep losses to predators on a California range: 1973-1983.** J. Range Manage. 38(5):418-421.
Abstract: Predation at the Hopland Field Station was evaluated for an 11- year period beginning in 1973. Of those lambs placed on range, an average of 2.7% were killed each year by predators. An average of 1.5% of the ewes were killed. When the number of missing animals which were killed was estimated, the average annual predation rate for lambs and ewes killed was 10.4% and 3.8% respectively. For all known ewe and lamb deaths, respectively, 45% and 26% were caused by predators, 14% and 28% died from causes other than predation, and 41% and 46% died from unknown causes. Of those sheep killed by predators, 89% were killed by coyotes, 8% by dogs, and 1% each by black bear, mountain lion, and golden eagle. More sheep were killed by coyotes from October to March

than from April to September, and the annual number of sheep killed by coyotes and dogs has increased since the beginning of the study. Not including the value of missing animals which were killed, the study period's value of livestock killed by predators was estimated to be $62,364.

Captive research coyote jumps livestock fence in pen trials, Fall 1974

5216. Scrivner, Jerry H., Walter E. Howard, and Roy Teranishi. 1985. **The use of diglyme as an odor-attractant solvent.** J. Wildl. Manage. 49(2):519-521.
Abstract: Because of its chemical properties, diglyme (DIGL) can be effectively used as an odor-attractant solvent. Both oil and water-soluble compounds, such as decanoic acid (DECA) and trimethylammonium decanoate (TMAD), are soluble in DIGL. In general, odorants dissolved in diglyme can be added to aqueous solutions, such as coyote urine, whereas odorants dissolved in an oil will not mix as well in an aqueous medium. Because DIGL and the control did not differ in attractiveness in the chemical additive, differences in odor attractiveness, such as those observed during this test for DIGL + DECA and DIGL + TMAD, could be attributed to the odors themselves. DIGL has a low freezing point so its use as an odor solvent increases the temperature range in which an odor can be effectively used. The attractants were presented to each coyote in randomized pairs in 60 trials. A total of two exposures per coyote was obtained for each attractant in 120 odor presentations. Preference (based on average time coyote spent at the odors) for the five odors was as follows: trimethylammonium decanoate (TMAD/sulfide combination > TMAD/sulfide/dodecanal combination > TMAD/sulfide/cheese-smelling additive combination > synthetic calf feces > TMAD. (Compounds related to TMAD and dodecanal are found in estrous coyote urine). The results are discussed in terms of specific behaviors elicited by the odors and how seasonality influences coyote-response time.

5217. Scrivner, Jerry H., Walter E. Howard, Roy Teranishi, and Daniel B. Fagre. 1985. **Toward a more effective coyote lure.** Rangelands 7(2):52-54.
Abstract: At present, trimethylammonium decanoate (TMAD) and related compounds continue to be the best synthetic attractants evaluated at the Hopland Field Station. Liver extracts are probably more attractive than TMAD and as attractive as the best commercially available lure but synthetic versions must be developed before they can be of practical use. Field testing of TMAD-based lures is in progress. While it is too early to make any definite conclusions about the effectiveness of TMAD, the results appear promising. With continued research, it should be possible to develop odor attractants which are both safe and selective and which can be effectively used to resolve animal damage problems.

5218. Scrivner, Jerry H., Walter E. Howard, and Roy Teranishi. 1987. **Effectiveness of a lure called "Coyote Control."** Wildl. Soc. Bull. 15(2):272-274.
Abstract: A new commercially-marketed coyote lure, Coyote Control®, is promoted as being a highly purified chemical pheromone produced by female coyotes in estrus. While captive coyotes at Hopland were more attracted to this product than to a control in standardized behavioral response tests, coyotes found the lure relatively unattractive, spending 9 times longer responding to a known attractant, trimethylammonium decanoate (TMAD). Our results do not support the manufacturer's claim that coyote control is a sex-specific coyote attractant.

5219. Scrivner, Jerry H., Roy Teranishi, Walter E. Howard, Daniel B. Fagre, and Rex E. Marsh. 1987. **Coyote attractants and a bait-delivery system.** Pp. 38-55 *in:* Protecting Livestock From Coyotes (J. S. Green, ed.), USDA Agric. Research Service, U.S. Sheep Exp. Stn., Dubois, ID.
Abstract: The frequency and duration of specific behavioral responses of captive coyotes (*Canis latrans*) to odor attractants were determined. Coyotes responded more to the acid and neutral fractions of coyote urine than to whole urine, and response time increased as the concentration of the urine fraction increased. Trimethylammonium decanoate (TMAD) was particularly attractive to coyotes and was used as a standard against which other odors were compared. Responses of coyotes to sheep liver extract equaled or exceeded those to TMAD. Diglyme was an effective odor solvent. Delivery systems were developed that capitalized on the ability of some odors to elicit a biting response from coyotes.

5220. Scrivner, Jerry H., Charles E. Vaughn, and Milton B. Jones. 1988. **Mineral concentrations of black-tailed deer diets in California chaparral.** J. Wildl. Manage. 52(1):37-41.
Abstract: The monthly level of phosphorus (P), sulfur (S), calcium (Ca), magnesium (Mg), and potassium (K) in the diet of black-tailed deer in mixed-age chaparral of California was determined during 1985-86. Forage samples were harvested by hand and analyzed using standard analytical methods. Annually, dietary concentrations averaged 0.16, 0.11, 0.49, 0.25 and 0.85% for P, S, Ca, Mg, and K, respectively. Levels of P and S were below the recommended minimum requirement during most months. In contrast, levels of Ca, Mg, and K were adequate during most months. To improve forage quality in mixed-age chaparral, managers can implement range improvement practices such as prescribed burning and chemical and mechanical brush control.

5221. Simmons, Gary D. 1990. **Animal damage control in California.** Pp. 14-15 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: The Animal Damage Control (ADC) program, now a branch of USDA's Animal and Plant Health Inspection Service, has had a long history in California. Historically, the program has focused on ADC problems associated with agriculture. However, as California's society changes and the state continues to become more and more populated, the program has had to devote more time and personnel to urban-related animal damage. Recently, the program has also become involved in the protection of endangered species. The control of migratory bird damage is a growing demand.

5222. Smith, Margaret F. 1978. **Relationship between genetic variability and niche dimensions among coexisting species of**

***Peromyscus*.** Ph.D. Dissertation, Univ. Calif. Berkeley. 279 pp.
Abstract: Genetic variability and niche width were measured in four species of *Peromyscus* at a series of study sites in California. Two measures of genetic variability were employed, variability at electrophoretic loci and variability in epigenetic characters (non-metrical skeletal variants). Niches width was measured in terms of the number of major habitat types occupied by each species over a 20-month period of time. Population densities were followed over the same period of time. Data on reproductive potentials were gathered from several sources. Species ranking in order of genic variability was strongly correlated with ranking based on variability in epigenetic characters. Neither measure of genetic variation was strongly correlated with the niche width measure. The niche width-genetic variation hypothesis is intuitively appealing and is supported by extensive mathematical models. However, insofar as field situations can be designed to test theory, the evidence suggests that other factors potentially contributing to the determination of variability levels must be considered. The possible effect of population dynamics of variability was also considered in this study. All species showed some potential for fluctuations in numbers over time. *Peromyscus maniculatus* has the greatest reproductive output of the four species; therefore its level of genetic variability would be least affected by population bottlenecks. Genetic variability may also be affected by overlying macro-geographic pattern of variation. In *P. californicus*, northern populations differ from southern populations in allele frequency at four out of seventeen polymorphic loci. Heterozygosity levels are high in the zone of contact, and also high in southern populations which presumably experienced fewer population bottlenecks. A multivariate analysis of variation in morphological characters identified two groups of populations, similar to the grouping based on variation at electrophoretic loci. The northern populations are assigned to the subspecies *Peromyscus californicus californicus*; southern populations are assigned to the subspecies *Peromyscus californicus insignis*.

5223. Stienecker, Walter E. 1977. **Supplemental data on the food habits of the western gray squirrel.** Calif. Fish and Game 63(1):11-21.
Abstract: Supplemental data from Kern, Mendocino, Sonoma, Napa, Shasta, and Tehama counties substantiates the feeding habits pattern of the western gray squirrel, *Sciurus griseus*, over much of its California distribution. Hypogeous fungi, oak acorns, pine nuts, and California bay fruit comprise the bulk of food eaten by gray squirrels. The types of fungi and principal food items are eaten in a pronounced seasonal pattern. Food habits of the Kern and Mendocino samples show that hypogeous fungi, acorns, pine nuts, California bay fruit, and vegetative leaf and stem fragments were the staple food items eaten by the western gray squirrels. These five food items contributed 95% of the total items eaten by Kern county squirrels and 90% of the items eaten by squirrels in Mendocino county. The 31 Sonoma county squirrels selected 99% of their food from the above five items. The food samples from Napa, Shasta, and Tehama counties indicated a similar pattern.

5224. Stroud, Dennis C. 1983. **Seasonal activity, demography, dispersal, and a population simulation model of the California ground squirrel, *Spermophilus beecheyi*.** Ph.D. Dissertation, Univ. Calif. Davis. 149 pp.
Abstract: Populations of *Spermophilus beecheyi* were studied for 3 years on northern California rangeland. Demographic data were collected from a population by live-trapping, marking, and releasing squirrels. The rate of population growth following cessation of control, reproduction, recruitment, survival, and population structure were computed. In addition, squirrels were trapped and removed from 6 colonies and the subsequent immigrants were continuously removed in order to obtain data on seasonality of dispersal and age and sex structure of dispersants. A comparison with other studies shows that the California ground squirrel exhibits a consistent demographic pattern over much of its geographic range: males are significantly heavier than females; juveniles reach a mature body size at about the same time in the active season; breeding season sex ratios are female biased (60%); yearlings form about one-half of the breeding adults of both sexes; most females (>85%) breed each year; approximately one-half of the recruitment of both sexes of juveniles is by birth on the area and one half by immigration of young rather than immigration of adults; total population loss (emigration plus mortality) is greater for juveniles than for adults, and greater for males than for females of both age groups.

5225. Teranishi, Roy, and Edwin L. Murphy. 1978. **Chemical identification of volatiles from coyote urine.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," San Angelo, TX, Aug. 23-24. 3 pp. + tables.
Abstract: Coyote urine collected at Hopland, CA and at Dubois, ID has been chemically analyzed in an effort to identify key compounds that are responsible for its attractancy to coyotes in the field. A liquid-liquid extractor was constructed to extract fractions from 40-liter batches of urine. Gas chromatograph-mass spectrometer equipment developed for food flavor research at the USDA Western Regional Research Laboratory was used to separate coyote urine into neutrals, basics, and acids fractions. Further chemical identifications will be made of sub-fractions, once those that are biologically active are identified by behavioral testing using captive coyotes. Tentative identification of constituent compounds in urine and estrous urine are given.

5226. Teranishi, Roy, Edwin L. Murphy, Donald J. Stern, Donald S. Balser, Walter E. Howard, and Daniel B. Fagre. 1981. **Bait posts.** Pp. 1852-1861 *in:* Proc. World Furbearer Conf., Vol. 3 (J. A. Chapman and D. Pursley, eds.), Frostburg, MD, Aug. 3-11, 1980. Univ. Maryland.
Abstract: The bait post is a vertical metal rod with a sidearm that holds a piece of sheepskin. The sheepskin is impregnated with odor and taste attractants and a coyote agent. The device could be used to apply tranquilizers, antifertility agents, or toxicants. Bait posts are simple, cheap, and rugged. They can be quickly and easily set out, then removed as soon as the target animals are eliminated. Because the posts can be removed, there will be little contamination of the environment. Excessive amounts of control agents, such as toxicants, can be avoided because of the efficient and specific delivery of the bait post. Testing to date has been limited mostly to pen studies.

U.S. Dept. of Agriculture

USDA scientists Edwin Murphy (left center) and Roy Teranishi (far right) apply an experimental coyote repellent to a ewe with assistance from Don Torell (right center), 1976

5227. Teranishi, Roy, Edwin L. Murphy, Donald J. Stern, Walter E. Howard, and Daniel B. Fagre. 1981. **Chemicals useful as attractants and repellents for coyotes.** Pp. 1839-1851 *in:* Proc. World Furbearer Conf., Vol. 3 (J. A. Chapman and D. Pursley, eds.) Frostburg, MD, Aug. 3-11, 1980. Univ. Maryland.
Abstract: Recent advances in analytical methods have permitted progress in human and insect olfaction research. These methods are now being applied in the study of chemical signals in vertebrates. Commercial grade oleic acid was steam-distilled for volatiles. It was found that the substances in these volatiles evoked licking and biting with coyotes (*Canis latrans*) as well as rubbing and rolling. Volatiles from coyote urine, especially the neutrals and acids, evoke similar lick-chew and rub-roll interest in coyotes. Capsaicin, the irritant material in red chili pepper, repels coyotes for a time. An odor signal, such as mint oil, seems to enhance the repellent action of red pepper. Some of the chemistry involved in isolation and identification and usage of above materials is discussed.

5228. Teranishi, Roy, Thomas H. Schultz, and Donald J. Stern. 1981. **Development of W-U coyote lures.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Twin Falls, ID, Aug. 11-12. 1 p.
Abstract: Cooperative research between the USDA Western Regional Research Center, the Hopland Field Station, and UC Davis have resulted in development of effective coyote attractants, designated as "W-U lures." Pen studies at Hopland using captive coyotes have show that trimethylammonium decanoate the most interest of any compounds tested, and that the compound's effect is enhanced by the addition of compounds such as putrescine, cadaverine, methyl ketones, and sulfides. As compared to pen studies, field trials with wild coyotes indicate such lures must be diluted, as they repel wild coyotes if used at full strength. There is a need for an efficient delivery method of coyote control agents such as antifertility compounds and toxicants. Bait delivery devices consisting of plastic pouches of sugar solutions can be utilized to deliver such compounds to coyotes. It may be more effective to strive for different lures for different seasons and situations, rather than to attempt to develop one "super" lure.

5229. Teranishi, Roy, G. Lorenz, Thomas H. Schultz, and Donald J. Stern. 1982. **Different coyote lures.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," Waco, TX, Aug. 10-11. 5 pp.
Abstract: Previous pen tests have shown trimethylammonium decanoate (TMAD) to be a very good coyote lure during fall and winter, but attractancy falls off during late spring in summer, when most predation on lambs occurs. TMAD was originally formulated after studying compounds emanating from the decomposition and rancidification process of meat. Because coyotes are known to be attracted to food odors, we have tested steam distillates volatiles from sheep liver. Sheep liver extract was fractionated, and most of the volatile compounds have been identified as hydrocarbons, aldehydes, esters, pyrazines, pyridines, and thiazoles. Some of these compounds have strong "meaty" odors to humans. Fractions and compounds are now being tested with pen coyotes by UC Davis cooperators. Volatiles from fresh estrous coyote urine have also been trapped and are being analyzed by a gas chromatograph-mass spectrometer-computer data system. Identified compounds will be tested for biological activity during the next coyote mating season.

5230. Teranishi, Roy, Thomas H. Schultz, Donald J. Stern, and Walter E. Howard. 1985. **Flavors as attractants.** Pp. 459-466 *in:* Topics in Flavour Research. Proc. 3rd Intern. Conf. (R. G. Berger, S. Nitz, and P. Schreier, eds.), Freising-Weihenstephan, Germany, Apr. 1-2.
Abstract: Trimethylammonium decanoate (TMAD) and methyl ketones were found to be coyote attractants. Some aldehydes and methyl sulfides found in coyote urine volatiles were also found to be good attractants. Odors attract coyotes from a distance, and sucrose increased the lick-chew response considerably once the coyote was brought to the bait. A maximum response per stimulus was noted as well as a seasonal response. Some chemicals were additive in effect, and others were not. All these factors have been considered, and lures formulated are now being field tested in various western states of the USA.

5231. Teranishi, Roy, and Walter E. Howard. 1986. **Coyote attractants.** SID Research Digest 4:4-6.
Abstract: A multidisciplinary team of wildlife biologists and chemists have systematically investigated coyote attractants. Some active compounds have been identified: aldehydes, organic acids, methyl sulfides, and methyl ketones. Some very powerful attractants have been suggested but not identified because the project has been terminated. Active compounds have been formulated into lures, and these lures have been patented. As soon as exclusive license is granted, these lures will be commercially available. Some of these lures are already in use on an informal basis; that is, samples have been given to interested parties. When the exclusive license is issued, these lures will be available commercially for animal damage control.

5232. Till, James A. 1992. **Behavioral effects of removal of coyote pups from dens.** Pp. 396-398 *in:* Proc. 15th Vertebr. Pest Conf. (J. E. Borrecco and R. E. Marsh, eds.), Newport Beach, CA, Mar. 3-5.
Abstract: Predation by coyotes (*Canis latrans*) upon domestic sheep is a serious economic problem for some sheep producers in the United States. One of the few depredation control techniques that has been quantitatively analyzed is denning, the process of removing pups from the dens of depredating coyotes. The significance of coyote prey selection and territoriality are discussed with regard to the efficacy of denning and possible future depredation management strategies.

5233. Timm, Robert M., Guy E. Connolly, Walter E. Howard, William M. Longhurst, Roy Teranishi, Edwin L. Murphy, and Robert S. Harris. 1975. **Coyotes respond to fractions of coyote urine.** Science of Biol. J. 1(3):87-89.
Abstract: Coyote urine has often been employed as an attractant to capture coyotes. In initial efforts to isolate the components responsible for attractancy, coyote urine was fractionated by sequential extraction with ether, NaOH, and HCl. Each of the four fractions obtained elicited rubbing and rolling responses when presented to captive coyotes.

5234. Timm, Robert M. 1977. **Responses of coyotes *Canis latrans* to urine odors.** Ph.D. Dissertation, Univ. Calif. Davis. 99 pp.
Abstract: Experiments were performed to test the hypotheses that 1) urine voided by male, anestrous female, and estrous female coyotes (*Canis latrans*) differs in quality, and 2) coyotes, under specific conditions, will demonstrate differential behaviors toward the three urine types. Both male and female coyotes exhibited significantly more interest in urine stimuli than in the control (distilled water). In tests conducted during pre-breeding (December through February) period, two male coyotes showed somewhat greater interest in estrous female than in anestrous female and showed least interest in male urine. In tests conducted during post breeding (March through June) period, one male exhibited significantly more interest in anestrous urine than in estrous urine and showed least interest in male urine. One female coyote showed somewhat more interest in male than in either type of female urine during the post breeding period. Overall, the data indicate that neither male nor female coyotes demonstrated significant discrimination among the three urine types. Reasons for the coyotes' overall

lack of discrimination are discussed in terms of the conditions under which the animals were housed and tested.

Guy E. Connolly

Extensive tissue damage and hemorrhage reveal this ewe was attacked and killed by a coyote, August 1974

5235. Timm, Robert M., and Guy E. Connolly. 1977. **How coyotes kill sheep.** Rangeman's J. 4(4):106-107. *Reprinted in* National Wool Grower 70(1):14-15, January 1980.
Abstract: Behavioral aspects of captive coyotes (*Canis latrans*) when attacking sheep (*Ovis aries*) are described and are illustrated with 6 photographs. Five of 12 coyotes, none of which had previous hunting or prey-killing experience, killed and fed upon 30- to 70-lb lambs at the first opportunity. Three additional coyotes did so in later tests. Dominant coyotes were more likely to attack and kill sheep than were younger, subordinate individuals. Because of characteristic attack and feeding patterns, coyote attack can often be differentiated from domestic dog attacks on sheep.

5236. Timm, Robert M., Walter E. Howard, Michael W. Monroe, Roy Teranishi, and Edwin L. Murphy. 1977. **A method for evaluating coyote scent baits.** Pp. 151-156 *in:* W. B. Jackson and R. E. Marsh (eds.), Vertebrate Pest Control and Management Materials. STP 625. Am. Soc. for Testing and Materials, Philadelphia, PA.
Abstract: A method for evaluating candidate coyote scent baits to make coyote control more selective has been developed. Each odorous compound is placed on a wad of cotton with a disposable tissue capsule secured between two metal plates. One or several horizontal or vertical scent stations or both can be placed within a test area into which a coyote is released. A single observer, located in a blind, can observe the animal's responses to the scents. The type of frequency of the coyote's responses to compounds can be recorded. Such information is valuable in selecting scents for use with various methods of coyote control.

5237. Timm, Robert M., Norman L. Gates, and Walter E. Howard. 1978. **Progress in identification of coyote scent baits.** *In:* Proc. Ann. Mtng., West. Reg. Coord. Comm. 26 "Evaluating Management of Predators in Relation to Domestic Animals," San Angelo, TX, Aug. 23-24. 6 pp.
Abstract: Responses of captive coyotes to chemical fractions of coyote urine and other candidate attractants are summarized from testing conducted at Hopland during 1978. Some urine fractions elicited interest at a level comparable with a standard synthetic fermented egg mixture.

5238. Timm, Robert M., and Terrell P. Salmon. 1988. **Ch. 12. Behavior.** Pp. 225-235 *in:* I. Prakash (ed.), Rodent Pest Management. CRC Press, Inc., Boca Raton, FL.
Abstract: A thorough knowledge of rodent behavior is required for effective prevention or control of rodent damage. Basic information on rodent behavior is presented, including behavioral components that are important in predicting, understanding, preventing, and controlling rodent damage to resources. Topics covered include physical abilities, perception of and response to stimuli (vision, sound, odor, taste, and reaction to objects), activity and movement, feeding behavior, and social behavior. The most successful rodent pests are those species that have adapted to a wide variety of situations. Behavioral adaptations are important in a species' ability to reach damaging population levels while avoiding certain control methods. The house mouse (*Mus musculus*), for example, is a highly successful species world-wide because, among other reasons, it possesses a network of behavioral adaptations that allow it to exploit a variety of living situations through a system that allows social flexibility. Rodents, as a group, are highly successful because of their biological and behavioral adaptations that allow them to exploit resources. In considering how rodent behavior affects rodent damage as well as rodent control, it is important to remember that rodent populations are not homogeneous. No matter how attractive and palatable a toxic bait may be to the majority of the population, there will likely be some individuals which will not feed sufficiently to consume a lethal quantity. No matter how well traps are placed, some individuals may not be captured. Despite considerable effort that may be taken to make an area rodent-proof by means of mechanical exclusion, some rodents will likely find their way in. Behaviors present within a rodent population may depend on a variety of factors including species, habitat, age of individuals, and prior attempts at control. A rodent control strategy that uses a variety of techniques and is "tailored" to the particular damage situation is most likely to be efficacious.

5239. Timm, Robert M., Terrell P. Salmon, and Robert H. Schmidt. 1988. **Key word standardization in vertebrate pest control.** Pp. 3-11 *in:* R. Bullard and S. Shumake (eds.), Vertebrate Pest Control and Management Materials. STP 974. Am. Soc. for Testing and Materials, Philadelphia, PA.
Abstract: Key words are becoming more useful as a means of locating bibliographic material. We expect their utility to increase as more persons use computers to store and retrieve information in databases. Previous ASTM Vertebrate Pest Control and Management Materials symposia proceedings have required the inclusion of key words; however, we have found that there is too much variability among these key words to enable them to be efficiently used. In the previous four symposia volumes, 104 articles used 469 different key words ($\bar{x}$ = 7.38 key words per article). Only 12 key words were used more than five times and 375 were used once. We found many examples of synonymous key words. When used in computer information systems, this lack of standardization makes retrieval difficult or less productive. We propose guidelines for choosing key words. Further, we give a suggested list of key words for articles dealing with vertebrate pest control. Use of these guidelines lend a greater uniformity to information storage and retrieval in this field by aiding authors, editors, persons searching the literature, and persons developing their own databases.

5240. Timm, Robert M., and Robert H. Schmidt. 1989. **Management problems encountered with livestock guarding dogs on the University of California, Hopland Field Station.** Pp. 54-58 *in:* Proc. 9th Gt. Plains Wildl. Damage Control Wkshp., Fort Collins, CO, Apr. 17-20. USDA For. Serv., Rocky Mtn. For. & Range Expt. Sta., Gen. Tech. Rep. RM-171. *Also published in*: Predator Management in North Coastal California. 1990. (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Univ. Calif., Hopland, CA, pp. 69-74.
Abstract: Guard dogs are being promoted and utilized as effective predator damage control tools under a variety of livestock management conditions. We report our experience over 1½ years

with 5 dogs, primarily Anatolian shepherd and Akbash dog breed. We discuss a number of behavioral and management problems we have encountered, some of which have not previously been reported in the literature. These include chasing vehicles and wildlife, predation on deer, and incompatibility of dogs with other predator damage control methods. Others have noted that some limitations on effective guard dog use include arid climates, widely-scattered livestock, rough terrain and heavy vegetative cover, and abundant predators providing severe pressure. While this description is apropos to the Hopland Field Station, it also is quite descriptive of most of the rangelands in the North Coast of California, traditionally one of the country's most important sheep-producing regions. It is our experience that guard dogs have limited effectiveness. Only one of our dogs is doing the type of job with which we are uniformly pleased; this, despite the fact that most of the dogs were proven working adults at the time we obtained them. From November 1987 through March 1989, we have expended approximately 500 person-hours of station labor (valued at $10.07/hr), in addition to expenditures totaling some $2500 for purchase and shipping of dogs. This does not include expenses for veterinary care, licenses, food, and other items necessary to the maintenance of the dogs. Unfortunately, the extent of problems we have encountered, especially considering our use of more and better-skilled labor than the average ranch, indicates to us that guard dogs are not a viable solution (either practically or economically) except in limited instances in our geographic area. We wonder whether our predator losses would have been more effectively reduced had we spent our time and funds on conventional control tools and methods. We would like to see further evaluation of the problems outlined above, and we intend to continue research on guard dogs in order to find means to solve some of these difficulties. A better understanding of the situations in which guard dogs will work effectively, and a fuller appreciation of some of the problems they create, will allow ranchers to make better decisions when planning a predator control strategy.

5241. Timm, Robert M. 1990. **Rat and mouse control for stored grain.** Pp. 91-108 *in:* Proc. III Nat. Stored Grain Pest Manage. Training Conf., Kansas City, MO, Oct. 20-25. Minnesota Ext. Serv., Univ. Minnesota.
Abstract: Damage to stored grains caused principally by house mice (*Mus musculus*) and Norway rats (*Rattus norvegicus*) is described. Guidelines are given for recognizing rodent infestations and damage. The biology of these rodents is summarized. Rodent control recommendations are given, including the following topics: sanitation, rodent-proof construction, trapping, rodenticide use, bait selection and placement, fumigants, and safety precautions.

Guy E. Connolly

UC Davis graduate student Bob Timm films observations of captive coyotes' responses to candidate attractants at HFS captive coyote facilities, July 1974

5242. Timm, Robert M. 1990. **Predator damage and research at the Hopland Field Station, University of California.** Pp. 3-9 *in:* Predator Management in North Coastal California (G. A. Giusti, R. M. Timm, and R. H. Schmidt, eds.), Ukiah and Hopland, CA. Hopland Field Station, Univ. Calif., Publ. 101.
Abstract: Predation on the Hopland Field Station's research flock is described and quantified. Coyotes are responsible for 77% of all predation-caused losses. Domestic dogs are a continuing, sporadic problem. Predation by mountain lions, bears, and golden eagles has increased in recent years. In addition to using the services of local Animal Damage Control specialists, the station has undertaken fence improvements and has attempted to utilize scare devices and guard dogs to reduce predation, without notable success. Research accomplishments in coyote biology and behavior are described. While the present level of predation threatens its ability to conduct animal science research, the station offers opportunity for continuing research to find more effective systems of predator damage control.

5243. Timm, Robert M., and Robert H. Schmidt. 1990. **Advances in non-lethal predation management.** Pp. 20-21 *in:* Beef and Range Workgroup Report, Div. Agr. & Nat. Res., Univ. Calif. Davis.
Abstract: The authors describe pilot efforts to control coyote predation on sheep at Hopland utilizing (a) livestock guard dogs and (b) siren-strobe light sheep-mounted collars designed to be audio-visual repellents to predators. While guard dogs were found to be of value in some instances, a number of behavioral problems not previously documented were encountered, including chasing vehicles and wildlife, preying on deer, and their incompatibility with other predator control methods. The "scare" collars were unreliable under field use due to moisture leakage causing electronic failure; thus, it was not possible to document their effectiveness.

5244. Timm, Robert M. 1991. **Commentary on vertebrate pest ecology.** Pp. 323-324 *in:* R. J. Gorham (ed.), Ecology and Management of Food-Industry Pests. FDA Tech. Bull. 4. Assoc. Official Analytical Chemists, Arlington, VA.
Abstract: Persons seeking to solve vertebrate pest problems need to have broad knowledge of the pest's biology. A holistic view is needed in order to develop optimum solutions. Damage control programs may fail because human dimensions, including sociological and cultural factors, have not been adequately considered. Further, wildlife damage control efforts are often less than successful because few people have adequate training in this discipline. Continuing research, both on basic questions as well as on the use of technologies, is needed. The general public needs to be better informed about the need for vertebrate pest control, as well as about the materials and methods employed to solve such problems in an acceptable manner.

5245. Timm, Robert M. 1991. **Ch. 31. Chemical control of rodent pests in bulk-stored grains.** Pp. 419-426 *in:* R. J. Gorham (ed.), Ecology and Management of Food-Industry Pests. FDA Tech. Bull. 4. Assoc. Official Analytical Chemists, Arlington, VA.
Abstract: This chapter focuses on control of rodents, principally house mice (*Mus musculus*) and Norway rats (*Rattus norvegicus*), by using currently-available rodenticides. Characteristics and proper uses of both anticoagulant rodenticides and non-anticoagulant rodenticides are discussed in detail, including safety precautions involved in pesticide use. Bait selection and formulation are reviewed, as is use of bait stations. The use of tracking powders and fumigants is described. Other topics covered include sanitation, the planning of rodent control programs, and maintenance of effective long-term control.

5246. Timm, Robert M. 1991. **Perceptions and realities: when does 2 + 2 = 5? Keynote address.** Pp. 3-7 *in:* Proc. 5th Eastern Wildl. Damage Control Conf. (P. D. Curtis, M. J. Fargione, and J. E.

Caslick, eds.) Ithaca, NY, Oct 6-9. Cornell Cooperative Extension.
Abstract: The public's perceptions of wildlife, wildlife damage management, and appropriate solutions to wildlife-human conflicts are discussed in terms of perception versus reality. America's developing animal welfare ethic is described, as well as the extreme view held by animal rights advocates. These issues are discussed briefly in the context of our urbanizing society, the role of agencies, ecological considerations, economics, and policy and professional ethics.

5247. Timm, Robert M., and Rex E. Marsh. 1993. **Wildlife damage management in North America: current status (Abstract).** P. 302 *in:* Proc. 6th Int. Theriological Congr. (M. L. Augee, ed.), Sydney, Australia, Jul. 4-10.
Abstract: North America has a relatively rich and varied fauna and a great deal of diversity of agricultural crops, made possible by the wide range of climatic conditions and soil types across the continent. It is therefore not surprising that wildlife damage is similarly diverse in nature, requiring a multitude of strategies to prevent or reduce damage where it occurs. Among the mammals most often in conflict with humans are certain genera of rodents, jackrabbits and moles. Deer are becoming an increasing problem in the eastern U.S.; other ungulates cause serious local problems. Predation, chiefly by coyotes, is a continuing concern to the livestock industry. Mountain lion predation is increasing in the western U.S. During the past several decades, blackbirds and starlings have caused widespread agricultural damage. Increased nuisance and damage problems involving waterfowl (ducks and geese) as well as gulls are also noted. A recent survey of state directors of the USDA Animal Damage Control revealed blackbirds and starlings, followed by waterfowl, as the number 1 and 2 needs for control methods research. Most wildlife damage conflicts are resolved by employing multiple methods from among the following categories: exclusion, habitat change, behavioral modification (scaring devices), and population reduction or removal of individual offending animals. Recent political pressures and changing attitudes have necessitated less reliance on lethal methods. Increased research effort is needed in order to provide cost-effective, acceptable methods of dealing with wildlife damage. The 3 major U.S. conferences on wildlife damage are mentioned.

5248. Timm, Robert M. 1994. **House mice.** Pp. B-31 - B-46 *in:* S. E. Hygnstrom, R. M. Timm, and G. E. Larson (eds.), Prevention and Control of Wildlife Damage. Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE.
Abstract: This chapter provides information on methods of preventing or solving damage caused by house mice (*Mus musculus*). Species identification, mouse biology and habits, and damage identification are described. A flow chart to aid decision-making in damage situations in included. Proven control methods are described including exclusion, habitat modification, and the use of rodenticides and traps.

5249. Timm, Robert M. 1994. **Norway rats.** Pp. B-105 - B-120 *in:* S. E. Hygnstrom, R. M. Timm, and G. E. Larson (eds.), Prevention and Control of Wildlife Damage. Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE.
Abstract: This chapter provides information on methods of preventing or solving damage caused by Norway rats, *Rattus norvegicus.* Species identification, rat biology and habits, and damage identification are described. Proven control methods are described including exclusion, habitat modification, and the use of rodenticides, fumigants, and traps.

5250. Timm, Robert M., and Walter E. Howard. 1994. **White-footed and deer mice.** Pp. B-47 - B-51 *in:* S. E. Hygnstrom, R. M. Timm, and G. E. Larson (eds.), Prevention and Control of Wildlife Damage. Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE.
Abstract: This chapter provides information on methods of preventing or solving damage caused by various species of *Peromyscus*, primarily the white-footed mouse *P. leucopus* and the deer mouse *P. maniculatus*. Species identification, mouse biology and habits, and damage identification are described. Precautions to avoid hantavirus infection are mentioned. Proven control methods are described including exclusion, habitat modification, and the use of rodenticides and traps.

5251. Timm, Robert M. 1994. **Pesticides: description of active ingredients.** Pp. G-23 - G-61 *in:* S. E. Hygnstrom, R. M. Timm, and G. E. Larson (eds.), Prevention and Control of Wildlife Damage. Cooperative Extension Division, IANR, University of Nebraska-Lincoln; USDA-APHIS-ADC; and Great Plains Agricultural Council, Lincoln, NE.
Abstract: Descriptions are provided for approximately 25 active ingredients used as pesticides, including toxicants, fumigants, and repellents, for vertebrate species. The current registered uses of each material are discussed briefly, as are the history and characteristics of each compound. Toxicity values are provided to a variety of target and non-target species, and publications providing additional information on each material are listed.

5252. Timm, Robert M. 1994. **Sources of information on wildlife damage control.** Pp. 345-351 *in:* Proc. 16th Vertebr. Pest Conf. (W. S. Halverson and A. C. Crabb, eds.), Santa Clara, CA, Mar. 1-3.
Abstract: Three hypothetical scenarios describe wildlife-human conflicts of the type that commonly occur in California. They illustrate the fact that information on how to solve such problems, and where to seek assistance, are scattered and may be difficult to locate. This publication lists, in tabular form, federal, state, and local agencies or private businesses that provide assistance or services to persons needing assistance with vertebrate pest problems. Also listed are available useful publications on this topic, including books, journals, magazines, and conference proceedings. Professional organizations that serve those working in this field are also listed.

5253. Timm, Robert M. 1994. **Training in wildlife damage control versus employers' needs: survey results (Abstract).** P. 96 *in:* Abstracts, 1st Ann. Conf., The Wildlife Soc., Albuquerque, NM, Sept. 20-25.
Abstract: A survey of employers of recent wildlife graduates reveals a disparity between the number of candidates trained in wildlife damage control and the employers' desire for such training. In many entry-level positions, wildlife damage control is part of the job's responsibility. Yet, few graduates are available who have such training. Among 90 colleges and universities with wildlife curricula that responded to a survey regarding the teaching of wildlife damage control, only 13 institutions reported the existence of a course with primary focus on this subject. Faculty and administrators responding to questions about why such a course was or was not offered often stated the subject was unimportant, was not of an academic nature, or could be adequately addressed by a few lectures within existing wildlife techniques or similar courses. A solution to this disparity appears to depend upon changing the attitudes of many of those who are responsible for wildlife curricula in colleges and universities.

5254. Timm, Robert M. 1995. **Predator losses and research at the UC Hopland Research and Extension Center (Abstract).** Pp. 29-30 *in:* Proc. Ann. Mtng., West. Res. Coord. Comm. 95 "Vertebrate Pests of Agriculture, Forestry, and Public Lands," Reno, NV, Nov. 14-16.

Abstract: This summarizes the influence of increased predation, particularly by coyotes, on the decline of the sheep industry in north coastal California and specifically at the Hopland R & E Center. Such predation, however, provides ample opportunity for research on coyote predation on sheep at this location. A USDA project of the Denver Wildlife Research Center under the leadership of Michael Jaeger and involving UC Berkeley graduate students has made good progress, using radiotelemetry, in identifying sheep-killing coyotes. Initial analysis suggests dominant, territorial adults are responsible for much of the livestock loss. In fall 1995, a research project was initiated to evaluate the effectiveness of livestock protection (LP) collars containing sodium fluoroacetate (Compound 1080). A research approach involving both radio-collared coyotes and LP collars can potentially much light on the dynamics and behaviors of coyotes in relation to livestock.

Anatolian shepherd "Brutus" was one of several guard dogs tested for their ability to guard sheep against coyote predation, 1990

5255. Timm, Robert M. 1996. **Update on predator research at Hopland: toxic collars and guard animals (Abstract).** Pp. 14-15 *in:* Proc. Ann. Mtng., West. Res. Coord. Comm. 95 "Vertebrate Pests of Agriculture, Forestry, and Public Lands," Reno, NV, Nov. 19-21.
Abstract: This summarizes a progress report on research investigating use of livestock protection collars ("toxic collars") and llamas as guard animals, conducted at the Hopland R & E Center under a grant from the Calif. Dept. of Pesticide Regulation. Some success with the collars has been achieved to date, and a problem of lost collars in large and rugged pastures has been resolved by use of radiotelemetry transmitters attached to the collars.

5256. Timm, Robert M., and A. Charles Crabb (Editors). 1996. **Proceedings, 17th Vertebr. Pest Conference.** Rohnert Park, CA, Mar. 5-7. 264 pp.
Abstract: This volume contains 54 papers presented at the 17th Vertebrate Pest Conference, held in Rohnert Park, CA. Reports concern aspects of management or research on various vertebrate pests including birds, rodents, and predators. A number of papers deal with issues of public health and safety, pesticide regulation, and other aspects of human-wildlife conflicts. While most papers represent research of management needs in North America, a number of papers presented by foreign participants are included.

5257. Timm, Robert M., and Rex E. Marsh. 1997. **Ch. 21. Vertebrate pests.** Pp. 954-1019 *in:* S. A. Hedges and D. Moreland (eds.), Handbook of Pest Control: The Behavior, Life History, and Control of Household Pests, Eighth Edition. Mallis Handbook & Technical Training Co., Cleveland, OH.
Abstract: This chapter is intended to assist structural pest control operators in dealing with nuisance and damage situations caused by a variety of vertebrate pests, particularly in urban and suburban habitats. Species most commonly involved in such problems are described, and viable control options are discussed. Included in this chapter are various rodents, armadillos, bats, opossums, raccoons, skunks, house sparrows, pigeons, starlings, snakes, toads, and frogs.

5258. Timm, Robert M. 1997. **Current status of vertebrate pest control programs and research in the United States.** *In:* Proc. Burrowing Rodent Damage Control Workshop, Edmonton, Alberta, Mar. 18-20. Alberta Agriculture, Food & Rural Development. 9 pp.
Abstract: Most wildlife damage conflicts are resolved by employing multiple methods from among the following categories: exclusion, habitat change, behavioral modification, and population reduction. Trends in wildlife damage management in North America are summarized, including the USDA Animal Damage Control program and the private Nuisance Wildlife Control Industry. Brief summaries of perceived trends in research, professional organizations, education, conferences and symposia, and publications are given. Situations regarding several species are summarized as representative of challenges facing wildlife researchers and managers: white-tailed deer, voles, black-tailed prairie dogs, ground squirrels, and pocket gophers.

5259. Timm, Robert M. 1997. **The future of burrowing rodent damage control: a prospectus for researchers, managers, and land custodians.** *In:* Proc. Burrowing Rodent Damage Control Workshop, Edmonton, Alberta, Mar 18-20. Alberta Agriculture, Food & Rural Development. 2 pp.
Abstract: While some recent trends in vertebrate pest management and damage control, such increased regulation, loss of former tools and methods, changing economics, and reductions in funding for research and management, are negative, there are other reasons to be optimistic about the future of this discipline. In the coming years, wildlife managers will be challenged to develop improved, integrated, ecologically sound strategies for preventing as well as controlling wildlife damage. New technologies, such as those from genetic engineering and immunology, may be adapted to our needs. Further implementation of Integrated Pest Management (IPM) principles to vertebrate species may pay dividends in terms of timely and economical control.

5260. Timm, Robert M. 1997. **Critters in the garden: current techniques in vertebrate pest control.** *In:* Proc. Master Gardener Int. Conf., Sacramento, CA, Jul. 16-19. Univ. Calif. Davis. 2 pp.
Abstract: An integrated approach to vertebrate pest management in gardens and on landscaped grounds is briefly described. A list of references useful to the home hobbyist or to the Master Gardener advising clients in included.

5261. Timm, Robert M., and Rex E. Marsh. 1997. **Feral pigeons.** Pest Control Technology 25(3):70, 74, 78-79.
Abstract: Damage by feral pigeons to structures, as well as nuisance and sanitation considerations, are described. Available control options include exclusion via commercial netting and bird-repellent devices and materials, building design, sanitation, and live trapping. Shooting, toxic perches, and a chemical frightening agent are available and are suitable for use in some situations.

5262. Timm, Robert M., Rex E. Marsh, Scott E. Hygnstrom, and Robert M. Corrigan. 1997. **Controlling rats and mice in swine facilities.** PIH-107 (revised) in Pork Industry Handbook, Purdue Univ. Coop. Extens. Service, West Lafayette, IN. 7 pp.
Abstract: This bulletin provides information on methods of preventing or solving damage caused by house mice (*Mus musculus*)

and Norway rats (*Rattus norvegicus*) in swine production facilities. Damage, including their potential role in spreading swine diseases, is described. Rodent biology and behavior is briefly discussed, as well as methods of inspecting premises for evidence of infestation. Control methods recommended include sanitation, rodent-proof construction, and population reduction using traps and/or rodenticide baits.

5263. Timm, Robert M., Gary D. Simmons, and John R. Hays. 1997. **Livestock protection collar use in California.** Pp. 24-32 *in:* Proc. 13th Gt. Plains Wildl. Damage Control Wkshp. (C. D. Lee and S. E. Hygnstrom, eds.), Nebraska City, NE, Apr. 16-19. Kansas St. Univ. Agric. Expt. Sta. and Coop. Extens. Serv. Univ. Nebraska-Lincoln.
Abstract: Use of the Livestock Protection Collar (LP Collar) containing sodium fluoroacetate began on a research basis in October 1995 at the UC Hopland Research and Extension Center. Registration for use in California only by certified ADC specialists was granted in early 1996, and operational use in three north coast counties began in early 1997. Preparation for beginning operational use dealt with concerns regarding user certification, hazardous waste disposal, and public relations. We report on the success to date of using LP Collars to remove sheep-killing coyotes. Incidents in which non-target predators including mountain lions have attacked collared sheep are also reported.

5264. Timm, Robert M. 1998. **Testimony: "Coyotes."** Hearing before Assembly Committee on Parks, Water and Wildlife, State of California, Nov. 30, 1998, Salinas, CA. 4 pp.
Abstract: Ways in which the coyote, *Canis latrans*, causes conflicts with humans are summarized, with emphasis on California. Historical and current methods of preventing or solving coyote predation on livestock are reviewed. Recent coyote research at the UC Hopland Res. & Ext. Center is described. Possible coyote impacts on deer populations in California are briefly discussed. An extensive list of literature citations regarding coyote, their impacts, and their management is provided.

5265. Timm, Robert M., and John R. Hays. 1998. **Livestock protection collar use at the U. C. Hopland Research & Extension Center.** *In:* Proc. Ann. Mtng., West. Res. Coord. Comm. 95 "Vertebrate Pests of Agriculture, Forestry, and Public Lands," Reno, NV, Nov. 17-19. 5 pp.
Abstract: We have used the Livestock Protection Collar (LPC) containing sodium fluoroacetate (Compound 1080) as our primary lethal means of controlling coyote predation on sheep and lambs at the Hopland R & E Center since fall 1995. During this time, we have avoided removal of coyotes that were not implicated in killing sheep on our 5,300-acre rangeland research facility. In 20 deployments of LP-Collared sheep, we have killed at least 9 (and possibly 11) sheep-attacking coyotes using this tool. Radio-telemetry of coyotes allowed recovery of 5 coyote carcasses, while also verifying earlier observations that most of our predation is caused by dominant, territorial adult coyotes. Our total loss rate of lambs (including "missing" animals) during 1997 was the lowest it has been in more than 20 years, and confirmed lamb losses to coyotes in 1998 were significantly lower than in any recent year. Our data suggest that selective removal of sheep-killing coyotes by means of the LP Collar, in the absence of other lethal predator control measures, may be a more effective strategy in our situation than conventional control. Unfortunately, passage of Proposition 4 on the November 1998 ballot banned the use of Compound 1080 in California, in addition to prohibiting use of steel-jawed leghold traps. Continuation of this study will depend upon our ability to formulate and effectively use an alternative toxicant in the LP Collar.

5266. Timm, Robert M. 1999. **Controlling coyote predation on sheep in California: a model strategy.** Final Report to Calif. Dept. of Pesticide Regulation, Contract #95-0241, UC Hopland Res. & Ext. Center, Hopland, CA. 20 pp.
Abstract: Over a three-year period, we conducted field trials in order to develop a more effective and selective strategy for reducing coyote predation on sheep and lambs at the UC Hopland Research and Extension Center. Our primary tool for selectively removing sheep-killing coyotes was the Livestock Protection Collar (LPC), a device designed to deliver a lethal dose of toxicant to any coyote that attacks a collared sheep and punctures the device. Additionally, we used llamas as guard animals in certain pastures in an effort to deter coyote attacks. We successfully reduced total confirmed lamb losses to coyote predation in the first two years of our study, primarily by our successful use of the LPC. Results from the third year suggest lamb loss to coyotes was higher, but the passage of Proposition 4 in November 1998 banned sodium fluoroacetate (Compound 1080), the registered active ingredient used in the LPC, leaving us without a tool for removing coyotes during a critical 4-month period. Overall, we did not find guard llamas to be consistently effective in protecting young lambs from coyote attack. However, our findings suggest that in some situations, specifically in smaller and more open pastures, llamas may be more likely to deter coyote or dog predation. To the extent that this occurs, the llamas may be useful tools in directing predation toward target flocks of sheep equipped with LPCs. To assist our research planning and the educational outreach efforts of our project, we established a Predator Research Advisory Committee that was composed of persons representing diverse interests and viewpoints. This Committee provided valuable input, and it also assisted our efforts in conveying our findings to our target audiences.

5267. Timm, Robert M., and Shari L. Dann (Editors). 1999. **Leading the way toward sustainability: Extension in the new millennium.** Proc. 9th Nat. Extens. Wildl. Fish. and Aquaculture Conf., Portland, ME, Sept. 29 - Oct. 2. Nat. Res. & Environ. Unit, Coop. State Res. Educ. & Extens. Service, USDA, Washington, D.C. 320 pp.
Abstract: This Proceedings contained summaries or entire text of approximately 70 presentations given by Extension Specialists or invited speakers at the 9th national meeting of wildlife, fisheries, and aquaculture specialists. Speakers during the plenary session included invited stakeholders and cooperators, agency personnel, and representative specialists. Panel discussions provided insight into the role of specialists and clientele expectations. Contributed presentations are grouped under the following categories: Sustainability, Biodiversity, and Community Land Use Planning; Conflict Resolution; Survival Skills; Wildlife and Aquatic Nuisance and Damage Issues; Aquaculture; Freshwater Fisheries; Youth Programs; Volunteer and Train-the-Trainer Programs.

5268. Timm, Robert M. 2000. **A history of wildlife damage management: twelve lessons for today.** Pp. 8-17 *in:* Proc. 9th Wildlife Damage Manage. Conf. (M. C. Brittingham, J. Kays, and R. McPeake, eds.), State College, PA, Oct. 5-8.
Abstract: The history of wildlife damage management in the United States, beginning with the roots of the federal Biological Survey, is examined. Selected lessons are drawn from history and applied to today's situation, in the hope that they will be useful to those who guide this profession in the 21st Century.

5269. Timm, Robert M. 2000. **House mouse.** Pest Notes Publ. No. 7483, Div. Agric. & Nat. Resour., Univ. Calif., Davis, CA. 4 pp.
Abstract: This bulletin recommend practical methods of preventing or solving damage caused by house mice (*Mus musculus*). Species identification, mouse biology and habits, and damage identification are described. Control methods for house mice include exclusion, habitat modification, and the use of rodenticides and traps. Rodenticides currently registered in California are listed, and safety

precautions for the safe use of these materials are included.

5270. Timm, Robert M. 2000. **An update on the activities of The Wildlife Society's Wildlife Damage Management Working Group (Abstract).** Pp. 35-36 *in:* Proc. Ann. Mtng., West. Res. Coord. Comm. 95 "Vertebrate Pests of Agriculture, Forestry, and Public Lands," Reno, NV, Nov. 14-16.
Abstract: This abstract summarizes a report detailing the recent history and accomplishments of the Wildlife Damage Management Working Group of The Wildlife Society. Included are brief discussion of the Group's sponsored publications, symposia at annual TWS conferences, and plans to host and sponsor the upcoming Wildlife Damage Management Conference to be held in April 2003.

5271. Timm, Robert M., and Guy E. Connolly. 2001. **Sheep-killing coyotes a continuing dilemma for ranchers.** Calif. Agric. 55(6):26-31.
Abstract: Predation on the Hopland Research and Extension Center's research sheep has increased substantially during the last several decades, as it did for commercial sheep producers in the North Coast region. Predator-caused losses in parts of the region reached unacceptable levels by the 1970s; concurrently, sheep inventories in Humboldt and Mendocino counties decreased dramatically. While domestic dogs, bears, golden eagles, and mountain lions have killed HREC sheep, approximately 75% of all predator-caused losses are due to coyotes. Lambs are more vulnerable to predation than are adult sheep, and at HREC, lamb loss approached or exceeded 10% of available lambs by the 1980s and approached or exceeded 20% three years during the 1990s. The Center evaluated a variety of lethal and nonlethal predator-control methods in an effort to find a predation control strategy that was cost effective and practical for other producers. Among the research approaches tested were potential coyote repellents, improved attractants for control devices, guard dogs and guard llamas, and electric fencing. These strategies, even when used in combination with assistance from the local predator control specialist, did not prevent significant losses of lambs and adult sheep. The most promising strategy tested was selective removal of only sheep-killing coyotes by use of the livestock protection collar containing sodium fluoroacetate. Selective removal of only sheep-killing coyotes, using this tool, resulted in successful reduction in lamb losses during the late 1990s. However, a November 1998 ballot initiative, "Proposition 4," banned all uses of sodium fluoroacetate as well as leghold traps in California, with no provisions for their research uses. This measure made it increasingly difficult to achieve effective control of predation on the Center's research sheep flock.

5272. VerCauteren, K. C., S. E. Hygnstrom, R. M. Timm, R. M. Corrigan, J. Beller, L. L. Bitney, M. C. Brumm, D. Meyer, D. R. Virchow, and R. Wills. 2000. **Development of a new model to assess rodent control in swine facilities (Abstract).** Pp. 202-203 *in:* Abstracts, 7th Ann. Conf., The Wildlife Soc., Nashville, TN, Sept. 12-17.
Abstract: We conducted a comprehensive economic analysis of rodent control in swine production facilities. An interdisciplinary working group was assembled to identify all necessary input variables and values associated with rodent damage and control. We incorporated data from production models, scientific literature, product literature, and personal experience into an interactive STELLA systems model. The model generates cost-benefit analyses and predicts outcomes of various levels of house mouse control for site-specific swine confinement facilities. We developed a website on rodent to promote use of the model, increase producer awareness of the costs associated with rodent damage, and provide information on integrated strategies for managing rodents. Although the model is relatively robust and comprehensive, we noted important gaps in research-based information, particularly associated with the economic impacts of rodents on diseases, food safety, quality assurance, and human dimensions. We will continue to improve the model and website as new information becomes available.

5273. Weckerly, Floyd W. 1992. **Territoriality in North American deer: a call for a common definition.** Wildl. Soc. Bull. 20(2):228-231.
Abstract: The concept of territoriality in deer (*Odocoileus* spp.) of North America has caused considerable debate. Several authors are skeptical of its occurrence in free-ranging populations, and others suggest that territoriality is common under certain environmental conditions and has significant effects on population dynamics, acquisition of resources, neonatal mortality, and spatial distribution. The purpose of this paper is to offer a common definition of territoriality, and three reasons are given as to why the classical definition should be used. This definition defines territoriality as defending an area. The defended area is considered to have resources that enhance reproductive success. The paper reviews studies which show evidence that deer have territorial tendencies, and concludes with suggestions for study designs to test for territoriality.

5274. Weckerly, Floyd W. 1993. **Intersexual resource partitioning in black-tailed deer: a test of the body size hypothesis.** J. Wildl. Manage. 57(3):475-494.
Abstract: To understand deer-habitat interactions important to making management decisions, it is necessary to ask questions in an evolutionary framework. Then, patterns that are detected can be evaluated in terms of how they potentially influence fitness, and to make more accurate predictions about changes in habitat use with changes in the environment. Intersexual resource partitioning in *Odocoileus* spp. is considered to be affected by sexual dimorphism in body size. Body size influences metabolic requirements which in turn presumably influence feeding behavior. Thus, I tested 5 predictions with black-tailed deer (*O. hemionus columbianus*) on Hopland Field Station, 1989-91, to determine if body size and its presumed impact on feeding behavior cause intersexual resource partitioning. Predictions, tested using radio telemetry and by measuring feeding behaviors of free ranging animals, ranged from general expectations about spatial distribution to specific predictions about feeding behavior. Males had larger ($P < 0.001$) home range sizes than females, except in summer. Based on body size considerations female home ranges should be 0.75 the size of males. Mean ratios mostly varied from 0.30 to 0.40. However, because of large variation, confidence intervals overlapped 0.75 during most seasons. Females exhibited a higher ($P < 0.05$) degree of site fidelity among seasons than males. The sexes differed ($P < 0.001$) in use of habitats among months, however, the pattern was not consistent. Generally, deer used more open habitats (grassland, chaparral grassland, and oak grassland habitats) in the wetter winter months, and more closed habitats (oak woodland, chaparral) in the drier summer months. There was considerable monthly variation in percent of time active ($P = 0.004$) but no difference ($P = 0.59$) between the sexes. Type of forage and percent of time a deer's head was in the feeding position were the only variables correlated ($P < 0.001$) with the number of bites taken in 7- to 10-minute feeding sessions. Type of forage accounted for 92% of the variation associated with number of bites. No differences were detected between the sexes in number of bites taken ($P = 0.34$) or percent of time head was in the feeding position ($P = 0.39$) on any forage type. There was no ($P > 0.42$) relationship between incisor breadth and body mass for each sex. Deer on Hopland Field Station exhibit sexual segregation, but the reason they segregate cannot be explained by differences in body size that may impact feeding behavior. The sexes do not partition resources to reduce intersexual competition. Harvest programs that assume no resource partitioning, however, ignore the possibility of intersexual density dependent effects being manifested because of individuals avoiding the opposite sex or

grouping with their own sex.

5275. Weckerly, Floyd W. 1994. **Selective feeding by black-tailed deer: forage quality or abundance?** J. Mammal. 75(4):905-913.
Abstract: Selectivity of forages by ungulates may be in response to the abundance of forages (forage-abundance hypothesis) or the nutrient quality of palatable forages (selective-quality hypothesis). I examined predictions of both hypotheses by measuring feeding behaviors of free-ranging black-tailed deer (*Odocoileus hemionus columbianus*) at Hopland Field Station. I observed 98 foraging sessions (foraging bouts of 7-10 min.) of adult males and females in all seasons and measured the number of bites, time the head was in the feeding position, type of forage, and biomass of plants along foraging paths. Selection (seconds per bite) was strongly correlated with biomass of forages only when deer foraged on dried grass or forbs. Seconds per bite varied considerably among types of forages: green grass-forbs ($\overline{X}$ = 1.3 s), leafy browse (3.8 s), dry grasses and forbs (6.1 s), acorns (19.6 s). The head was in the feeding position significantly less when foraging on dry grasses and forbs, and acorns than when deer foraged on green grass-forbs and leafy browse. Selectivity (seconds per bite) of leafy browse and acorns by deer was correlated with Julian date, an index to nutrient content. Number of bites was positively related to time the head was in the feeding position only when deer foraged on green grass-forbs. Selectivity of deer ostensibly varied in response to nutrient content, and searching was probably the dominant process influencing selectivity on most types of forages.


Guy E. Connolly

5-year-old fallow deer buck at HFS, December 1974

5276. Wehausen, John D. 1973. **Some aspects of the natural history and ecology of fallow deer on Point Reyes peninsula.** M.S. Thesis, Univ. Calif. Davis. 68 pp.
Abstract: The fallow deer on Point Reyes peninsula stem from known introductions of 15 animals in 1942, 11 in 1947, and 2 in 1954. Their present population at the end of 1973 is close to 500 animals, which range over 25 square miles. The present doe population of 260 can be explained by a constant increase of 11% a year. This relatively low rate may be largely a function of suboptimum fawn production, found to be 52 fawns per 100 does. This in 27% below the potential. It is conjectured that predation on young fawns before they appear in the open is an important factor depressing fawn production. Parasite levels in the fallow deer on Point Reyes were not found to be significant, thus parasites do not presently play an important role in the population dynamics of these deer. Fallow deer on Point Reyes show a strong preference for grassland species in their diet. As protein levels of grasses drop in spring, certain forb species maintaining higher summer nutrient levels become the sought-after species, until fall rains initiate fresh grass growth. In late summer, when forage quantity and quality were at a minimum, protein levels in the rumina of fallow deer were found to be adequate. This indicates that presently this fallow deer population undergoes no marked nutritional stress during the year. The large quantities of fat found on autopsied animals substantiates their healthy condition. The diet of both fallow and axis deer on Point Reyes appears to coincide with that of cattle. There is no indication that forage is in short supply for these deer species, thus little competition presently exists between them. Both deer species do appear to compete with the cattle, which require dietary supplementation during late summer and autumn. The extent of this competition is not known.

5277. Wilson, Randolph A., Patricia Manley, and Barry R. Noon. 1991. **Covariance patterns among birds and vegetation in a California oak woodland.** Pp. 126-135 *in:* Proc. Symp. Oak Woodlands and Hardwood Rangeland Manage., Davis, CA, Oct.31 - Nov. 2, 1990. USDA For. Serv., Pac. Southwest For. & Range Expt. Sta., Gen. Tech. Rep. PSW-126.
Abstract: We sampled characteristics of vegetation and estimated abundances of bird species on 23 plots representing a continuum of tree densities of the blue oak phase of the Coast Range foothill woodland near Hopland, California. Fifty-one bird species were found breeding. Cavity nesters dominated the bird community in a variety of tree species for nesting, highlighting the importance of tree species richness. Large deciduous oaks were found to be important as granary trees for acorn woodpeckers, as well as substrates for nest cavity excavation by primary cavity nesters. Large evergreen trees were important in providing natural cavities to many secondary cavity nesting bird species. Both individual bird species and guilds showed few covariations with tree density. We discuss why a guild approach is not always a useful way to describe relationships between bird abundance and vegetation. Effects of spatial scale and plot size on observed bird/habitat relationships are discussed.

5278. Wilson, Randolph A. 1992. **Nesting success of the plain titmouse, *Parus inornatus,* as an indicator of habitat quality in blue oak woodlands.** M.A. Thesis, Humboldt State Univ. 89 pp.
Abstract: This study examines the relationship between variation in reproductive success of the plain titmouse and variation in its nesting habitat. The study spanned two nesting seasons (1986 and 1987) in blue oak woodlands at the Hopland Field Station. Plain titmouse were censused on 23, 5-ha study plots, representing a continuum of tree densities. To discriminate between high and low quality habitat, I examined: 1) nesting success, 2) population density, and 3) stability of territory occupancy. Results indicated that nests in sparse plots averaged both fewer eggs laid and fewer young fledged than dense plots. Plain titmouse abundance increased with increasing tree density up to approximately 200 trees/ha, after which they decreased. In comparing nest placement and cavity variables, successful nests were placed in substrates with smaller diameters and greater cover than unsuccessful nests. Nest trees had twice the number of natural cavities and a greater number of broken branches than random trees. These results support the theory that passerines may choose nest sites in habitat surrounded by many potential, though unused nest sites, making the probability of predator detection less for the actual nest site. Numbers of black oak trees (which contain a greater than expected number of cavities) and total basal area were also greater around nest than random trees, lending more evidence to this hypothesis.

Guy E. Connolly

OTHER SUBJECTS

6001. **Annual Reports, Berkeley Seismological Laboratory.** 1994 - 2001. Univ. Calif. Berkeley.
Abstract: This series of annual reports summarizes activities of the Berkeley Seismological Laboratory, an organized research unit of UC Berkeley. The laboratory operates a regional network of 20+ digital broadband and strong motion seismic stations, the Berkeley Digital Seismic Network (BDSN), including an automated station at the Hopland Res. & Ext. Center that has been operational since 1994. The reports are published on a fiscal year basis (July 1 - June 30) and summarize the year's activities, data acquisition, research progress, and publications. Data obtained from the Hopland site are integral to many of the Laboratory's research projects and resulting publications.

Farm advisor Bruce Bearden (l) and Al Murphy (r) check new weather station equipment, Niderost Pasture, Winter 1965

6002. Bearden, Bruce E., and William H. Brooks. 1978. **The Climate of Mendocino County.** Mendocino Co. Coop. Extension, Ukiah, CA. 38 pp.
Abstract: This report uses climatological data from 41 stations, including three at the Hopland Field Station, to characterize the climate of Mendocino County. Four general area climates can readily be identified: maritime, coastal, transitional, and interior. Winter temperatures are moderate throughout the county, while summer temperatures are cool along the coast and moderately warm in interior valleys. Freezing temperatures are observed every year at inland points, but not along the coast. Precipitation in Mendocino County is concentrated in the winter-half of the year with 85 to 90% of the annual total falling from October through May. Summer rain is more common in the higher mountains. Evapotranspiration values were computed to estimate the water use of growing crops throughout the county. These data suggest that cover crops would use from 26 to 32 inches of water annually, with the higher requirements being in the lower Russian River valley. Cumulative heat units, or degree-days, were also estimated for the various locations with the county. These values indicate that of the 5 grape-growing regions designated in California, the 3 cooler regions occur in Mendocino County.

6003. Becker, J. C., P. J. Richerson, T. H. Suchanek, A. C. Heyvaert, D. G. Slotton, and Charles E. Vaughn. 1996. **Clear Lake coring project: the history of anthropogenic impacts 1700-1996.** Draft Interim Report, Div. of Environ. Studies, Univ. Calif. Davis.
Abstract: Sediment cores are very useful in determining the extent of impacts, both anthropogenic and natural, to aquatic ecosystems and their surrounding basins, as there are many parameters that indicate the conditions at the time of deposition. They have been used successfully to reconstruct the extent of human impacts on aquatic ecosystems. Physical and chemical parameters such as organic matter, P, C, N, Hg and other pollutants can be used to show changes to inputs into the system. Biological constituents such as pollen and diatoms are affected by changes in land use or eutrophication of the systems. Our preliminary data indicate that the Sulphur Bank Mercury Mine appears to have been a point source for Hg contamination in the lake since before western expansion into Clear Lake basin. Total N and C, along with $\%H_2O$ in the sediment, all decline in the upper or more recently deposited sediments, while total P tends to increase. This suggests that there have been recent increases in inorganic constituents (and probably basin derived sediment) and quite probably an increase in the sedimentation rate. Technological changes that dropped the unit cost of earth moving, with the invention of the bulldozer and allied equipment, likely caused the large, relatively recent, coincident changes in so many parameters in the cores.

6004. Becker, J. C., P. J. Richerson, T. H. Suchanek, A. C. Heyvaert, D. G. Slotton, J. G. Kim, and Charles E. Vaughn. 1997. **Ch. 9 The Role of the sulphur bank mine site (and associated hydrological processes) in the dynamics of mercury transport and bioaccumulation within the Clear Lake ecosystem.** *In:* The history of mercury deposition in the Clear Lake watershed, as deduced from lake sediment cores. Interim Final Report to EPA Region 9 Superfund Program, Univ. Calif. Davis, pp. 163-194.
Abstract*:* To investigate mercury loading in Clear Lake, CA over the past ca 250 yrs, we raised sediment cores from multiple sites on the lake. These cores are ca 2.5 m long and span 200-300 yrs of the lake's history. ^{210}Pb dating, performed on one representative core to date, yielded an average sedimentation rate of 1.33 cm/yr. Total (primarily inorganic) mercury, methyl mercury, and a number of other parameters were measured at 5 cm core intervals. Nearly all parameters show major changes beginning at depths ranging from 25-80 cm (depending on the core), corresponding to an estimated date of 1927. Organic matter, total carbon, water content and total nitrogen fractions all show major decreases above this depth. A peak in bulk density and minimum values for percent water at depths corresponding to about 1971 suggest a period of heavy inorganic erosional input into Clear Lake. Both inorganic and methyl mercury concentrations show striking increases (5-10 fold, depending on the core) above the 1927 horizon. There is also a smaller increase in inorganic and methyl mercury at 95-100 to 145-150 cm depths (depending on the core). This horizon is too at the far end of ^{210}Pb dating capabilities, but almost definitely represents the early episodes of mercury mining. Peak inorganic mercury concentrations occur at an estimated date of 1961 and a modest decline has occurred since. Methyl mercury profiles are more complex. Interestingly, the first 75 years of European settlement in the Clear Lake basin (including the most productive years of mercury mining) appeared to have barely detectable effects despite considerable presence after the 1870s. Impacts since 1925 are much more dramatic. We hypothesize that around 1925 powered

earth moving equipment became more available and economical, leading to dramatically increased soil erosion. Road building and similar activities in the basin increased at about this time, and the Sulphur Bank Mercury Mine began to be operated using large-scale open pit techniques.

6005. Becker, J. C., P. J. Richerson, T. H. Suchanek, A. C. Heyvaert, D. G. Slotton, J. G. Kim, and Charles E. Vaughn. 1997. **Human disturbance in the Clear Lake watershed (Lake County, California) since 1800.** Pp. 134-146 *in:* Proc. 1st Ann. Clear Lake Sci. and Manage. Symp., Lakeport, CA, Sept. 13, UC Davis Clear Lake Environ. Res. Center.
Abstract: To investigate multiple stresses on Clear Lake, CA over the past ca 250 years, we raised sediment cores from the three basins of the lake. These cores are ca 2.5 m long and span 200 - 300 years of the lake's history. We present the results for our, as yet, most thoroughly analyzed core. ^{210}Pb dating yielded a 1.33 cm/yr average sedimentation rate for this core. Total (primary inorganic) mercury, methyl mercury, organic matter content, carbon, nitrogen, phosphorus, and percent water content were measured at 5-cm intervals down the core. Nearly all parameters show major changes at depths of 75 - 80 cm, corresponding to an estimated date of 1927. Organic matter, total carbon, water content, and total nitrogen all show significant decreases above this depth. A peak in bulk density and minimum values for percent water at depths corresponding to about 1971 suggest a period of heavy inorganic erosional input into Clear Lake. Both total and methyl mercury concentrations show major increases in concentration (roughly 10-fold) above the 1927 horizon. There is also a smaller rise in total and methyl mercury at 145 - 150 cm deep in the core. This horizon is beyond ^{210}Pb dating capabilities, but most likely represents the early episodes of mercury mining, which started in 1873 at the Sulphur Bank Mercury Mine, located on the lake's shore. Peak total mercury levels occur at an estimated date of 1961 and a modest decline has occurred since. Methyl mercury profiles are more complex. Interestingly, the first 75 years of European settlement in the Clear Lake basin (including the most productive years of Sulphur Bank Mercury Mine) appeared to have barely detectable effects on methyl mercury deposition despite considerable presence after the 1870s. Impacts since 1925 are much more dramatic. We hypothesize that around 1925 powered earth moving equipment became much more available, and the cost per unit of earth moved dropped drastically, leading to dramatically increased soil erosion. Road building and similar activities in the basin increased about this time, and the Sulphur Bank Mercury Mine began to be operated using large scale, open pit techniques.


Guy E. Connolly
Early-morning clouds linger at Maude's Glade, July 1974

6006. Brooks, Colin, and Adina M. Merenlender. 2000. **How the GIS was used to map and quantify policy impacts.** Calif. Agric. 54(3):19-20.
Abstract: GIS data and methods were used to analyze Sonoma County's Vineyard Erosion and Sediment Control Ordinance, adopted in February 2000, which set standards for the development of new vineyards on certain slopes. The purpose was to quantify the areas that would be affected by this regulation, in order to better evaluate the policy and to assist decision-makers. We conclude that most future vineyard development will fall under Level I (requires notifying the Agricultural Commissioner's office, and a 25-foot stream setback). No more than 36% (and more likely closer to 20%) of future vineyard development will fall under the more stringent regulations (Levels II and III, requiring 50-foot setbacks and development of a certified erosion control plan).

6007. Burgy, Robert H. 1965. **Hopland Experimental Watershed II and the December 1964 - January 1965 flood.** Calif. State Board of Forestry, Special Session on Flood Review, Feb. 26, 1965, Sacramento, CA. 9 pp.
Abstract: The 1964-65 storms in the North Coast basins were of significant magnitude causing severe flooding of lands and related economic losses. The experience and responses obtained from experimental Watershed II at Hopland were similar to those of other streams in the region. While this event did not produce the maximum discharge of record, it did produce high runoff volumes and large quantities of soil erosion, largely associated with land slips. Prolonged rainfall conditions like those of 1955 and 1964 can be expected to occur occasionally with consequent heavy runoff and flooding.

6008. Gee, Lind S., Douglas S. Neuhauser, Douglas S. Dreger, Michael E. Pasyanos, Robert A. Uhrhammer, and Barbara Romanowicz. 1996. **Real-time seismology at UC Berkeley: the rapid earthquake data integration project.** Bull. Seismological Soc. Am. 86(4):936-945.
Abstract: The Rapid Earthquake Data Integration project is a system for the fast determination of earthquake parameters in northern and central California based on data from the Berkeley Digital Seismic Network and the USGS Northern California Seismic Network, including data from instrumentation at the Hopland R & E Center. Program development started in 1993, and a prototype system began providing automatic information on earthquake location and magnitude in November of 1993 via commercial pagers and the Internet. Recent enhancements include the exchange of phase data with neighboring networks and the inauguration of processing for the determination of strong-motion parameters and seismic moment tensors. Data from the Hopland R & E Center's seismology instrument installation are included among data from some 13 field sites from San Luis Obispo to the Oregon border.

6009. Gillette, Donna L. 1998. **PCNs of the coast ranges of California: religious expression or the result of quarrying?** M.A. Thesis, California State University, Hayward. 127 pp.
Abstract: In the Coast Ranges of California have been found approximately 84 petroglyph sites which have been identified as rock art which contain an element that is known as PCN or Pecked Curvilinear Nucleated style. This style consists of incised or pecked circles and ovals, which have raised centers, have had the centers removed, or are otherwise embellished. Nearly all of them are found on blue chorite schist boulders. Three of these are located on the UC Hopland R & E Center. Some of these sites have been suggested as ideological in nature, while others are

suggested as technological, and were utilized as source material for artifacts such as charmstones and for bowl quarrying similar to soapstone quarries on Catalina Island. This thesis addresses the geographical distribution of the sites and interpretation of their use as religious expression or quarry site.

6010. Gomes, W. R. 2001. **UC Research and Extension Centers: statewide system provides local answers to local needs.** Calif. Agric. 55(6):3-5.
Abstract: This introduction to the special issue of California Agriculture that commemorates Hopland's 50th anniversary summarizes the UC Research & Extension Center system, its mission, and its focus. A map of the Hopland R & E Center shows its elevational range, major physical features, and its location within the north coast region of California. Brief descriptions of the other 9 Centers within the system are provided.

6011. Gowans, Kenneth D. 1958. **Soil survey of the Hopland Field Station.** Agric. Expt. Sta. Publ. 70, Univ. Calif. 33 pp.
Abstract: The Hopland Field Station occupies a portion of an intermountain valley of the Coast Range. The general topography of the area is the result of the Russian River entrenchment into the Coast Range mountains. The soil survey of this area used standard USDA methods. Soils and vegetation were mapped concurrently. The survey reflects a large number of soil separations which are a result of the many kinds of parent material, the variable rainfall differences in elevation, and variable vegetation. Areas as small as 2 acres were mapped, and 17 series were recognized in the final survey area. Geologically, the area is part of the Franciscan Formation (Jurassic), consisting of plastic and chemical sediments with some intrusive igneous rock. The hard, fractured sandstones and shales are the dominant rocks. The medium-textured soils of the Laughlin, Sutherlin, Maymen, Los Gatos, Hugo, and Josephine series are found on these rocks. The Stonyford and Sobrante series have formed on localized areas of basalt. Yorkville soils are derived from areas of glaucophane schist which has a rather wide distribution in the area. Small areas of ultrabasic rocks and metamorphic rocks of basalt and sandstone occur in the area, and the Climax and serpentine Henneke and Montara soils have developed there.


Guy E. Connolly
Parson's Creek flowing at Headquarters road crossing, January 1973

6012. Heaton, Emily, and Adina M. Merenlender. 2000. **Modeling vineyard expansion, potential habitat fragmentation.** Calif. Agric. 54(3):12-18.
Abstract: We used a statistical modeling technique called logistic regression analysis, and a geographic information system (GIS), to map areas of possible future vineyard expansion in Sonoma County, based on data about vineyard development from 1990 through 1997. The goal of this research was to develop a model that would improve our understanding of vineyard expansion patterns at a landscape scale (for instance, including an entire county). The approach involved identifying landscape characteristics that were associated with vineyard development and mapping the areas that were undeveloped in 1997. We used the results to map where habitat removal and fragmentation could result from vineyard expansion. This method, although still under development, is designed for county- or regional-scale analysis to assist land-use planners, natural resource protection agencies and land conservation programs in protecting valuable environmental resources while sustaining a vital agricultural economy.

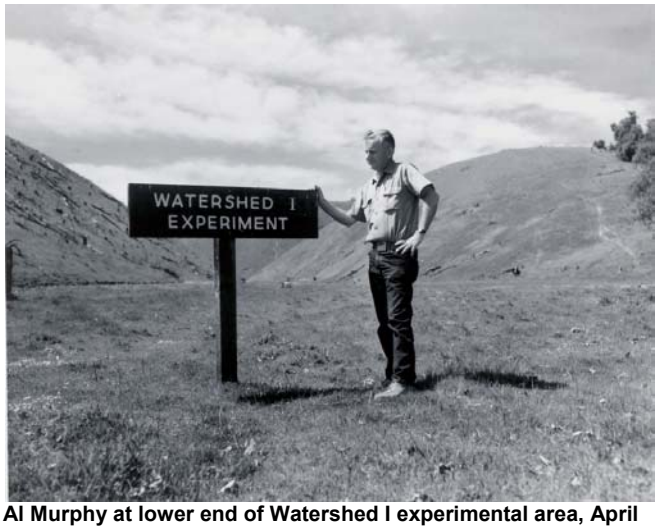
6013. Lewis, David C., and Robert H. Burgy. 1962. **Water use by native vegetation and hydrologic studies.** Ann. Rep. No. 3, 1961-62, Dept. of Irrigation, Univ. Calif. Davis, pp. 48-65.
Abstract: The objective of the "hydrologic studies" project is to collect and analyze quantitative and qualitative data on water and sediment yield resulting from watershed conversion of native vegetation species to herbaceous species. These data are to be collected from study areas covering a range of geographic, geologic, and climatic conditions, including sites in Placer, Madera, and Mendocino Counties. An intensive groundwater exploration investigation was conducted during the past year at the two watersheds at the Hopland Field Station. Hydrologic studies at this site have been in progress for 10 years. Watershed I has been converted from an oak and chaparral cover to a grass cover. The oak trees on Watershed II have been chemically killed by cut-surface basal applications. Rainfall, runoff, and erosion data are continuously collected on these pilot watersheds. Results from Watershed I have shown that a zone of seepage under the gauging structure is through jointed, unweathered sandstone underlying the gauging structure at depths greater than 10 feet. In the years following the vegetative treatment, it had become evident that streamflows of <1 ft^3/sec percolate into the channel bed at a point approximately 100 ft above the gauging station; at times this same flow reappears in the stream channel immediately below the gauging station. This results in a considerable portion of the water yield from the watershed being unmeasured. In order to determine the best procedures for measuring this water, 7 observation wells were drilled into the stream channel immediately above and below the gauging structure. These wells supplement 5 wells that had been drilled previously. Tables and figures provide details on these wells and the data from them gathered in 1962; 3 methods of measuring the flow are described. Groundwater contour maps are presented for 5 different dates, January through April. In Watershed II, an intense network of ground water observation wells was installed across the canyon at the gauging structure during the first half of 1962. This network is illustrated in figures, and tables provide data on well depth and depth to water table as measured weekly during May, June, and early July 1962. The geology of the canyon section of Watershed II at the gauging station consists principally of a jointed sandstone formation. With the formation there are steeply dipping shear zones containing large quantities of clay. The weathering of the formation extends to greatest depth near the stream channel. Where conditions permitted, pumping tests were made of the wells immediately after completion of drilling. Preliminary results on Hopland Watershed II indicate that the rates of downstream ground water seepage in the canyon section at the gauging structure are not high. A description of material from observation well drilling is given as well as charts of drawdown versus time for pumping test to determine the permeability of subsurface material.

6014. Lewis, David C., and Robert H. Burgy. 1963. **Water use by native vegetation and hydrologic studies.** Ann. Rep. No. 4, 1962-63, Dept. of Irrigation, Univ. Calif. Davis, pp. 68-78.
Abstract: Hydrogeologic studies on Hopland Watershed II have progressed with the collection of information needed to estimated groundwater outflow from this 210-acre watershed. Pumping tests on the 2-inch observation wells were initiated in spring 1963. Methods of conducting these tests to determine the permeability of the fractured and jointed rock have been perfected and preliminary results are presented. Elevations of the water level in 11 observation wells for each week during the 1962-63 fiscal year. Responses of groundwater levels to precipitation can be seen seasonally; in general, such responses appear as a rapid increase in water level followed by a quite rapid decrease. Only the wells at the higher elevations, away from the stream channel, showed a net increase in water level over the rainy season. In order to gain a better understanding of groundwater dynamics following rainfall, three continuous groundwater level recorders were installed in Wells 1, 2, and 3 during fall 1962. Data from these is presented in tabular format. The influence of pumping tests conducted during June 1963 are indicated by a sudden drawdown followed by recovery of the groundwater level. Estimates of the range of transmissibilities and permeabilities obtained in pumping tests on the various wells are given.

6015. Lewis, David C., and Robert H. Burgy. 1964. **Hydraulic characteristics of fractured and jointed rock.** Ground Water 2(3):4-9. *Presented at:* National Water Well Exposition, Sept. 29 - Oct 3, 1963, San Francisco, CA. *Also reprinted as:* Lewis and Burgy (1964) in: Water Use by Native Vegetation and Hydrologic Studies.
Abstract: Hydrogeologic studies in foothill watersheds at Hopland and in Placer County have included diamond-core drilling, installation of observation wells, and pump tests. Detailed study of recovered cores has provided reasonable estimates of porosity. Pumping tests of the 2-inch-diameter wells have given estimates of the transmissibilities ranging from 6 to 600 gallons per day per foot. Test data from several wells indicate that the hydraulics of water movement in jointed rock systems is not governed by the usual mathematical models. The influence of large drawdowns on the drawdown vs. time relationship in an unconfined aquifer merits additional investigation employing analytical and model approaches. Data obtained from pumping tests done at the watershed studied are generally not suited to analysis by the nonequilibrium equations developed for confined aquifers.

6016. Lewis, David C., and Robert H. Burgy. 1964. **Water use by native vegetation and hydrologic studies.** Ann. Rep. No. 5, 1963-64, Dept. of Irrigation, Univ. Calif. Davis, pp. 57-70.
Abstract: Collection of groundwater and hydrologic data from watersheds at the Hopland Field Station, as well as watersheds in Madera Co., is continuing on a routine basis. No new results have been obtained from analysis of these data during the past year.

6017. Lewis, David C., and Robert H. Burgy. 1966. **Water use by native vegetation and hydrologic studies.** Ann. Rep. No. 6, 1964-65, Dept. of Water Sci. & Engineering, Univ. Calif. Davis, pp. 73-92.
Abstract: The validity and usefulness of the tracer dilution method for determining apparent groundwater velocities has been reported in the literature for the past decade. When a well penetrates unconsolidated sands and gravels, the technique of injecting short half-life radioisotopes into a well and then monitoring the tracer dilution at several depths within the well appears justified since tracer dilution occurs rapidly. However, when apparent groundwater velocities are small, the use of non-isotope tracers and manual sampling appears to be desirable. This is particularly true if small observation wells are utilized in which a monitoring probe could scarcely be inserted. The studies reported here, conducted on watersheds at Hopland and in Placer Co., show that the method of tracer dilution can be extended to use in fractured and jointed rock media when hourly or semi-daily samples are taken to determine the dilution. Good agreement between the hydraulic conductivity values calculated from the tracer dilution method and from pumping tests were obtained. The dilution method, however, is more economical from the standpoint of time, cost, and repeatability of the studies. When the dilution method is employed, results can be obtained from a large number of wells within one week whereas with pumping tests, approximately one per day can be conducted under the most favorable conditions. One man can handle the manual sampling and sample analysis in the dilution method, whereas two men are normally required for the operation of pumping test equipment. In addition to providing support for the validity of the tracer dilution method based on field experience, the studies reported here show the utilization of non-isotope tracers to extend the method to porous media have very low apparent groundwater velocities.



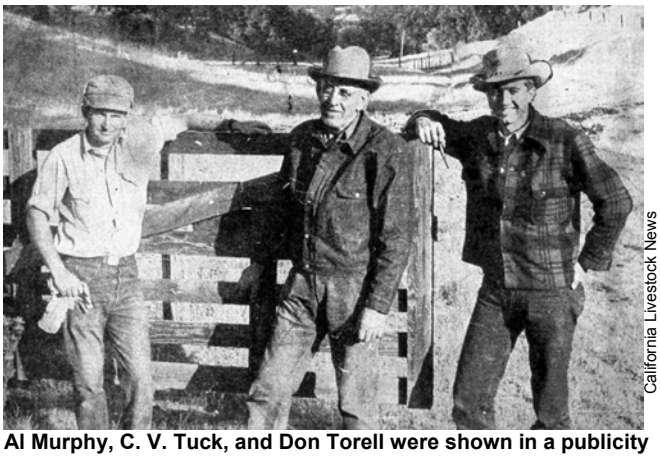
Al Murphy at lower end of Watershed I experimental area, April 1966

6018. Lewis, David C., George J. Kriz, and Robert H. Burgy. 1966. **Tracer dilution sampling technique to determine hydraulic conductivity of fractured rock.** Water Resources Research 2(3):533-542.
Abstract: Groundwater in foothill and mountain watershed areas commonly occurs in fractured rock. The small well diameters and low apparent groundwater velocities in fractured rock require modification of normal techniques for the investigation of unconfined groundwater movement. The determination of hydraulic conductivity by the tracer dilution method normally employs injected radioisotope tracers. The dilution is determined by monitoring the isotope activity in the well with a scintillation probe. A modification of this method using fluorescent dye tracers and physical sampling and analysis to determine dilution was applied in small wells with consistent results. One of two study sites was at the Hopland Field Station, where 11 2-inch observation wells were established in the Watershed II study area. Hydraulic conductivities of 0.02 to 0.5 ft/day were determined in 16 wells.

Where comparison was possible, the values agreed favorably with hydraulic conductivities determined by pumping tests.

6019. Meadows, Robin. 2001. **Hopland celebrates 50 years of rangeland research.** Calif. Agric. 55(6):6-9.
Abstract: This introductory article in the special issue of California Agriculture, celebrating Hopland's 50th anniversary, gives a brief history of the "Hopland Field Station" and of the current Research and Extension Center system. Notable is the shift in research emphasis from production agriculture topics in the 1950s and 1960s to research on natural resources and environmental management issues in the 1980s and 1990s. A brief synopsis of current, major research areas describes each of the following: sheep breeding and predator control; disease epidemiology and related disciplines; rangeland research; watersheds and water quality; and habitat restoration.

6020. Merenlender, Adina M. 2000. **Mapping vineyard expansion provides information on agriculture and the environment.** Calif. Agric. 54(3):7-12.
Abstract: Vineyards are expanding rapidly in California's coastal counties due to a booming wine market. This change in land use has led to public debate over natural habitat removal, over-production of wine grapes, loss of agricultural diversity, and changing scenery. Using a geographic information system (GIS) to map and analyze vineyard expansion in Sonoma County, approximately 11,600 acres of new vineyards were identified from 1990 through 1997. The total acreage was calculated to be at least 48,000 acres in 1997, 20% more than reported by county agricultural officials. Compared to vineyards established before 1990, a higher percentage of vineyards planted between 1990 and 1997 were located on hillsides that supported oak woodlands. Oak woodlands support a majority of the region's biodiversity, provide ecosystem goods and services, and have aesthetic value. This research was designed to document the effects of recent vineyard expansion on Sonoma County's hardwood rangelands and to provide tools for informed discussion and decision-making by land-use planners, farmers, residents, and environmentalists.


California Livestock News

Al Murphy, C. V. Tuck, and Don Torell were shown in a publicity photo at the inception of the Hopland Field Station, 1951

6021. Murphy, Alfred H., R. Merton Love, and William C. Weir. 1976. **Building a research program: 1951-1976.** Calif. Agric. 30(7):5-6.
Abstract: The Regents of the University of California established the Hopland Field Station to investigate problems pertaining to the conservation and use of natural resources represented in California's rangelands. Originally, a Range Land Utilization subcommittee was appointed to develop specific recommendations to be implemented on the station including: establishing grazing study areas; setting aside sheep-free areas for wildlife studies; making a botanical survey; setting up permanent photo points on the rangelands; and establishing two sheep flocks. Early studies on sheep grazing capacity, soil inventories, plant surveys, and forage analysis gave researchers a basis for study into the complex problems associated with the management of all rangeland resources. Subsequent research, much of it in long-term studies, covered a diverse range of subjects and had contributed significantly to rangeland management programs in California and many other parts of the world.

6022. Richerson, P. J., K. Stauffacher, T. H. Suchanek, C. E. Vaughn, D. Thibeau, and S. J. Why. 1997. **The phosphorus cycle in an iron limited lake.** Pp. 54-63 *in:* Proc. 1st Ann. Clear Lake Sci. and Manage. Symp., Lakeport, CA, Sept. 13, UC Davis Clear Lake Environ. Res. Center.
Abstract: Clear Lake has been known as an iron limited phosphorus rich system since the work of Horne and colleagues in the early 1970s. The DWR water quality monitoring time series documents 3 "regimes" in the phosphorus cycle. Large amounts of P cycled in the lake on an annual basis from 1969-73. From 1974 to 1987, the amounts of P in the water column in late summer-early fall was much less. Dissolved phosphate was often at or near detection limits, except in the late summer and fall peak of total P. From 1987 onwards, P levels in the lake began to increase steadily until 1991, when peak late summer values of dissolved P reached several hundred ppb. At peak P levels, about 80% of total phosphorus is dissolved. Algae are able to use only a small portion of the total P released from sediments. Iron limitation of nitrogen fixation keeps the lake strongly nitrogen limited, resulting in the extra-ordinarily clear-water years since 1990. We have investigated the dynamics of cycling from the sediments using grab samples and short cores. Each year, there is a large loss of iron/aluminum bound P from the sediments in the late summer and fall, corresponding with the large increase in dissolved phosphorus in the overlying water. During the winter and spring, this large mass of phosphorus is absorbed into the sediments, mostly in the upper 3-5 cm. The mass of P cycling annually has been dropping slowly since the end of the drought.

6023. Richerson, Peter J. 1998. **Possible impacts of SO_4 and acidity discharges from Sulphur Bank Mine on the Clear Lake ecosystem (Abstract).** *In:* Ann. Clear Lake Sci. and Manage. Symp., Lakeport, CA, Oct. 24, UC Davis Clear Lake Environ. Res. Center.
Abstract: We have raised five cores raised from Clear Lake in order to test the hypothesis that increased erosion since the 1920s is responsible for nutrient increases that favored cyanobacteria (bluegreen algae). Heavy earthmoving machinery began to be employed on a large scale in the late 1920s and early 1930s, and observations of the lake noted a deterioration of water quality about the same time. As we have reported previously, several parameters in the cores are consistent with this "bulldozer" hypothesis. After about 1927, cores became markedly drier, higher in magnetic minerals, lower in organic matter, and lower in nitrogen than previously, as if increasing amounts of inorganic erosion products were diluting the organic matter deposited from the water column. However, careful calculations of dry matter deposition rates reveal a constant deposition post 1927 rate in one core and a lower deposition rate in the other four. This anomaly may result from the small sample of deposition rates or from misdating deeper horizons in the core. An alternative hypothesis is that some other change that began about 1927 is responsible for the changes in core

properties. The changes in organic matter content etc. are closely correlated with a 10-fold increase in mercury in the cores. Open pit mining at Sulphur Bank began in 1927 and no doubt resulted in discharges of sulfate and acidity from the mine site, as well as mercury. The amounts are difficult to measure, but our preliminary estimates suggest that 50-90% of the current sulfate load to Clear Lake comes from Sulphur Bank Mine. Sulfate reduction is one of the most important microbial processes in Clear Lake sediments. A sulfate conveyor in which sulfide produced by sulfate reduction diffuses upward to be re-oxidized to sulfate seems necessary to account for gross rates of sulfate reduction measured by Erin Mack. A sulfate conveyor enhanced by increased sulfate loading could result in a more thorough oxidation of the sediments, and hence in the lower organic matter and nitrogen content of post 1927 sediments. Lower organic matter in turn may result in less water retention. Sulfide concentrations near the sediment surface probably regulate the iron cycle in Clear Lake. Under conditions of high sulfate, the less organic sediments will permit deeper penetration of sulfate and oxygen into the sediment surface and reduce the concentrations of sulfide that otherwise inhibit the release of soluble iron. Sediment redox and sulfur speciation likely affect the speciation and magnetic properties of iron minerals. Acidity form the mine will result in the selective dissolution of sediment minerals. Although the mechanisms are as yet unclear, it is possible that sulfate and/or acidity loads from Sulphur Bank Mine played a major role in the deterioration of Clear Lake's water quality. The recent drought was a crude test of this hypothesis. The amount of sulfate and soluble iron decreased during the drought, bringing on the relatively clear water years beginning in 1991.

6024. Richerson, Peter J., Thomas H. Suchanek, Jesse C. Becker, Alan C. Heyvaert, Darell G. Slotton, Jae G. Kim, Xiaoping Li, Laurent M. Meillier, Douglas C. Nelson, and Charles E. Vaughn. 2000. **Ch. 7: The history of human impacts in the Clear Lake Watershed (California) as deduced from lake sediment cores.** Pp. 119-145 *in:* Kate M. Scow, Graham E. Fogg, David E. Hinton and Michael L. Johnson (eds.), Integrated Assessment of Ecosystem Health. Lewis Publishers, Boca Raton, FL.
Abstract: We have raised sediment cores to investigate multiple stresses on Clear Lake, CA over the past 250 years. Earlier work suggested the hypothesis that the use of heavy earth-moving equipment was responsible for erosion, mercury, and habitat loss stresses. Such stress would have first become significant about 1925 to 1930. The cores are about 2.5 m long and span 200 to 300 years of the lake's history. We present the results for our, as yet, most thoroughly analyzed core. ^{210}Pb dating yields an estimated 1.2 cm/yr average sedimentation rate for this core. Total (primary inorganic) mercury and a number of other parameters were measured at 5-cm intervals down the core. Nearly all parameters show major changes at depths of 75 to 80 cm, corresponding to an estimated date of 1927. Organic matter, total carbon, water content, and total nitrogen all show significant decreases above this depth. A peak in inorganic deposition rate and minimum values for percent water is present at a depth corresponding to about 1971. Inorganic mercury concentrations show major increases in concentration (roughly tenfold) above the 1927 horizon. There is also a smaller uptick in total mercury at 145 to 150 cm deep in the core. This horizon is beyond ^{210}Pb dating capabilities, but most likely represents the early episodes of mercury mining which started in 1873 at the Sulphur Bank Mercury Mine located on the lake's eastern shore. Peak total mercury levels occur at an estimated date of 1961 (last mining was in 1957), and a modest decline has occurred since. Interestingly, the first 75 years of European settlement in the Clear Lake basin (including the most productive years of Sulphur Bank Mercury Mine) appeared to have barely detectable effects on core properties despite considerable presence after the 1870s. Changes since 1925 are much more dramatic. The large increase in mercury beginning about 1927 corresponds to the use of heavy equipment to exploit the ore deposit at Sulphur Bank Mine with open pit methods. The increase in inorganic sediment load during the last 75 years is substantial in this core, but is not replicated in other cores. Increases in sulfate and/or acidity loading from the mine may be responsible for the dramatic changes seen in the upper 75 to 80 cm of the core.

Research associate Chuck Vaughn prepares sample for lab analysis, April 1996

6025. Schulz, R. K., J. P. Moberg, and Roy Overstreet. 1959. **Some experiments on the decontamination of soils containing strontium 90.** Hilgardia 28(17):457-475.
Abstract: The possibility that large areas of the landscape could become contaminated with strontium 90 through fallout or reactor accidents has necessitated studies of means of decontaminating soils containing radio-strontium. In this work three possible methods were investigated: 1) displacement by electrolytes and leaching; 2) physical immobilization using asphalt preparations; and 3) placement at depth. Of the various electrolytes used, ferric chloride and hydrochloric acid were most effective. The use of the electrolytes followed by leaching with 5 feet of irrigation water displaced up to 90% of the ^{90}Sr below the surface 6 inches. This, however, was not sufficient decontamination so that the land could be put back into agricultural use. In addition, the procedure is very expensive. By spraying the soil surface with asphalt, it was found that 97% of the ^{90}Sr could be removed by peeling off the hardened crust. When the crust was cultivated into the soil profile, however, the ^{90}Sr gradually became available to plants. In order to investigate the possibility of reducing the uptake of ^{90}Sr by deep plowing, experiments were conducted in lysimeters in which the isotope was placed in bands at different depths in the soil. When the soil was cropped to barley, a marked reduction of uptake of ^{90}Sr with depth of placement was observed. In irrigated barley the content of ^{90}Sr per gram of plant material was reduced 10-fold when the depth of placement was increased from 2 inches to 2 feet.

6026. Schulz, R. K., and H. H. Riedel. 1961. **Effect of aging on**

fixation of strontium 90 by soils. Soil Sci. 91(4):262-264.
Abstract: With the passage of several years, a small fixation of ^{90}Sr was found to exist in a nonexchangable form in soils. This fixation probably takes place, in part, by incorporation of $CaCO_2$ crystals when soils contain this material. In all soils studied, fixation appears to be caused by entry of the ^{90}Sr into such solid phases as strontium or calcium phosphates or other crystals containing strontium or calcium.

6027. Suchanek, T. H., P. J. Richerson, D. C. Nelson, C. A. Eagles-Smith, D. W. Anderson, J. J. Cech, R. Zierenberg, G. Schladow, J. F. Mount, S. C. McHatton, D. G. Slotton, L. B. Webber, B. J. Swisher, A. L. Bern, and M. Sexton. 1999. **Evaluating and managing a multiply-stressed ecosystem at Clear Lake, California: a holistic ecosystem approach.** *In:* Int. Congr. for Ecosystem Health, Sacramento, CA, Aug. 15-20.
Abstract: Multiple management objectives are especially challenging in a system subjected to numerous ecological stresses. Clear Lake is an ancient, shallow, highly productive lake with rich habitats for breeding and migrating waterfowl, fish-eating birds, and mammals. Local residents also use its abundant resources for recreation, water supply, and active sport and commercial fisheries. Yet it also has a well-documented history of natural and anthropogenic stresses. Earthquakes, fires, floods, and droughts have shaped the landscape, the flow pattern of outlet streams, and the ecological relationships within the lake's dynamic ecosystem. Anthropogenic stresses since the mid 1800s include 1) contaminants such as heavy metals (mercury, arsenic, and copper), organochlorine and other pesticides (DDD, DDT, methyl parathion, fluoridone) and sewage overflows; 2) numerous watershed and creek modifications, and 3) abundant species introductions. These have also contributed to significant alterations in the native fauna and flora of Clear Lake. Ultimately, our ability to understand and manage multiply-stressed ecosystems will benefit greatly from studies of systems like Clear Lake. As such, this site represents an excellent laboratory ecosystem to study the effects of multiple stresses and their management. The USEPA-funded Center for Ecological Health Research program located on the UC Davis campus is studying the multiple uses and stresses associated with managing this important resource.

6028. Timm, Robert M. 1990. **Hopland Field Station: Watershed I and II.** Pp. 88-89 *in:* R. Z. Callaham (ed.), Case Studies and Catalog of Watershed Projects in the Western Provinces and States. Wildland Resources Ctr., Div. Agric. & Nat. Resour., Univ. Calif., Berkeley, CA.
Abstract: Study sites designated Watershed I and Watershed II at the Hopland Field Station are described in this index. Data for each site is outlined in terms of location, geology, topography, vegetation, research treatments and results, and published reports.

6029. Uhrhammer, Robert A., S. J. Loper, and B. Romanowicz. 1996. **Determination of local magnitude using BDSN broadband records.** Bull. Seismological Soc. Am. 86(5).
Abstract: The Berkeley Seismographic Station operated standard Wood-Anderson torsion seismographs from 8 April 1928 through 16 January 1994. These seismographs are historically significant in that their seismograms have been used to determine local (Richter) magnitude of earthquakes that occurred in northern and central California and adjacent regions, routinely since 1948 and ad hoc back to 1928. Broadband digitally recording seismographs were co-sited at four stations with Wood-Anderson instruments to compare the records. The Wood-Anderson seismographs became redundant for the purpose of determining the maximum horizontal trace amplitudes once procedures were developed to synthesize their seismograms accurately from the broadband digital recordings. Operation of the Wood-Anderson seismographs was subsequently discontinued. This article demonstrates the ability to determine an unbiased measure of local magnitude from synthesized Wood-Anderson seismograms, thereby maintaining a seamless catalog of local magnitude at Berkeley.

Jack Kelly Clark

Entrance to vault containing UC Berkeley Seismograophic Station instruments, established in 1994, Watershed I

6030. Uhrhammer, Robert A., William Karavas, and Barbara Romanowicz. 1998. **Broadband seismic station installation guidelines.** Seismological Research Letters 69(1):15-26.
Abstract: As the deployment of broadband seismometers becomes increasingly common practice, the need for specific installation guidelines has emerged. Indeed, in order to operate efficiently, broadband instruments require a much more controlled environment than standard short-period seismometers. In order to help those who are contemplating the installation of broadband instruments, we present here some guidelines on the installation of broadband seismic stations. Rather than trying to cover all aspects of the installation procedures in detail, we concentrate on those aspects of the installation procedures in detail, we concentrate on those aspects which have the largest impact on the overall performance of a seismic station housing a broadband seismometer and a high-resolution (24-bit integer) data logger. The two aspects of the installation process which most influence the overall performance of the broadband seismometer are the construction of the seismic pier and the application of thermal insulation around the sensor and pier. As an example, we cover some details about the installation and the operating characteristics of the Berkeley Digital Seismic Network (BDSN) broadband stations recently installed. Included are photos from preliminary instrumentation at Hopland, prior to installation of the permanent BDSN station. Routine monitoring of the performance of all broadband seismometers in a network is essential for early detection and identification of problems which occur with the broadband seismometers. Spending adequate time in the scouting for suitable sites, in the recording and analyzing of the background noise characteristics, in the planning and design, and in the vault construction and installation of a broadband station is highly recommended. The resulting broadband station will generally perform very well, have a low noise level, and require very little maintenance. When installing broadband instrumentation in an existing vault, its performance can be improved significantly, and inexpensively, be appropriately insulating the seismometer and the pier to minimize temperature fluctuations. After broadband instruments are installed, routine monitoring of the signal mean and background noise PSD levels to facilitate early identification of problems with the seismometers is recommended.

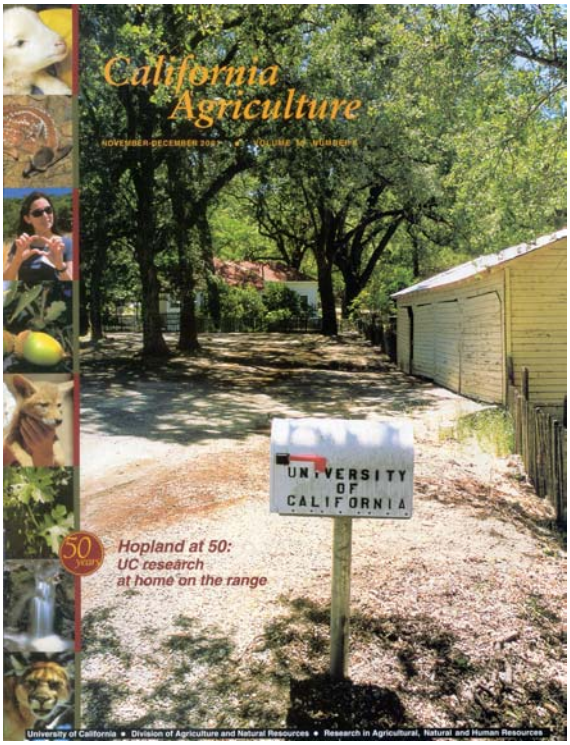

Mary Conner

Group of inner-city high school students enjoying natural resources field trip at Hopland, July 1993

6031. Why, S., R. Smythe, C. Vaughn, and B. Lamphere. 1994. **Ch. 5: External nutrient loading.** Pp. V-1 to V-38 *in:* P. J. Richerson, T. H. Suchanek, and S. J. Why (eds.), The Causes and Control of Algal Blooms in Clear Lake. Final Report, Lake County/UCD Clean Lakes Project, Univ. Calif. Davis.
Abstract: The external phosphorus load to Clear Lake averages about 160 MT/yr. By far the largest load is erosion products from non-point sources. Groundwater is apparently a negligible source, and wastewater, even counting overflows in high water years, is a comparatively small source. Greatest losses are to the sediments, with losses to the outflow averaging about 25 MT/yr. Exchanges between sediments and water are also large terms in the budget. All terms are highly variable, with large loads, high sediment storage, and high outflow during wet years, and very much lower loads in low runoff years. In low load years, the sediments can act as a large source of phosphorus. Tule Lake removes from half to two thirds of the sediment load of Scotts Creek, indicating the important role that wetland loss has played in the eutrophication of Clear Lake. Iron loading and cycling is, unfortunately, difficult to evaluate. A model of phosphorus cycling under reduced loading conditions shows that load reduction will likely lead to a loss of phosphorus from the water column over time. While sediment storage correlates strongly with creek loading, the relationship becomes weak with low loading. As a result, this term introduces significant uncertainty to the model.

6032. Why, S., C. Vaughn, and B. Lamphere. 1994. **Ch. 6: Internal loading.** Pp. VI-1 to VI-11 *in:* P. J. Richerson, T. H. Suchanek, and S. J. Why, (eds.), The Causes and Control of Algal Blooms in Clear Lake. Final Report, Lake County/UCD Clean Lakes Project, Univ. Calif. Davis.
Abstract: Clear Lake, like many shallow, productive lakes, absorbs most of its external load of phosphorus into its sediments during winter and recycles it into the water column in summer and fall. This regenerated phosphorus is termed the “internal load.” An important question for management purposes is the size of the internal store of phosphorus in sediments that can contribute to the nutrition of algae even after the external supply of nutrients from the basin is reduced. Clear Lake has about 3,500 metric tons (MT), 3.860 short tons, of phosphorus in its upper 10 cm (4 inches) of sediment. Of this total about 500 MT has cycled into the water during the recent drought-influenced years. Under more normal conditions from the mid-1970s to mid-1980s, only perhaps 100-200 MT cycled. Most of the active phosphorus is contained in the iron/aluminum-bound fraction, of which about half of the total amount stored in the top 10 cm of sediments in spring recycled to the water in summer and fall of 1992 and 1993. The amount of actively cycling phosphorus during drought conditions was 3 times the external gains and losses in more typical years, like 1974-86. If the pools of active phosphorus behave according to simple dilution principles, decreases in the external load will cause a reasonably prompt response in lake nutrient levels. If average losses to the sediments initially remain at about 130 MT/yr, losses down Cache Creek at 25 MT/yr, and the external load is substantially reduced to, say, half current averages of 160 MT/yr, the loss of actively cycling phosphorus will be rapid. If the sediment storage term varies with load, more of the burden of diluting the sediment-stored load will fall on the Cache Creek outflow, slowing the response to reduced inputs. If the sediments act as a source of phosphorus after load reduction, as in the drought years, response to load reduction could be very slow.

6033. Winsome, Thäis. 2000. **Earthworm ecology in California.** Oaks 'n' Folks 15(1):4-5.
Abstract: Research at Hopland suggests displacement of native by non-native earthworms is closely tied to land use. In undisturbed habitats, native species predominate. In croplands, orchards, and irrigated pastures, native species are rare or absent, displaced by the more prolific non-native species. The role of earthworms in influencing soil fertility is explained. Preliminary findings suggest that differences exist in the ways that native and non-native earthworms process soil nutrients; these differences may have long-term consequences for soil fertility in pastures. Both groups enhance the availability of nitrogen and phosphorus, but native species tend to be active at the soil surface for a longer period of time throughout the year.



Cover of Nov/Dec 2001 HREC 50th anniversary issue of *California Agriculture*

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