

UC Agriculture & Natural Resources

Proceedings of the Vertebrate Pest Conference

Title

Population densities and disease surveys of wild pigs in the coast ranges of central and northern California

Permalink

<https://escholarship.org/uc/item/0cw2x4s1>

Journal

Proceedings of the Vertebrate Pest Conference, 17(17)

ISSN

0507-6773

Authors

Sweitzer, Rick A.
Gardner, Ian A.
Gonzales, Ben J.
[et al.](#)

Publication Date

1996

POPULATION DENSITIES AND DISEASE SURVEYS OF WILD PIGS IN THE COAST RANGES OF CENTRAL AND NORTHERN CALIFORNIA

RICK A. SWEITZER, and IAN A. GARDNER, School of Veterinary Medicine, Department of Medicine & Epidemiology, University of California, Davis, California 95616.

BEN J. GONZALES, Arizona Department of Fish and Game, 2221 West Greenway Road, Phoenix, Arizona 85051.

DIRK VAN VUREN, Wildlife, Fish & Conservation Biology, University of California, Davis, California 95616.

WALTER M. BOYCE, School of Veterinary Medicine, Department of Pathology, Microbiology & Immunology, University of California, Davis, California 95616.

ABSTRACT: In 1994 and 1995, 233 different wild pigs were captured during population research at seven research sites focused primarily in the coastal regions of central and northern California. Mark-resight data and information on wild pig movements were used to assess wild pig population densities at those sites. Population densities ranged from 1.01 wild pigs/km² in Mendocino County in 1994 to 3.32 wild pigs/km² in Santa Clara County in 1995. Comparisons of population densities between years at three research sites suggested that wild pig populations increased in 1995 in response to favorable forage conditions after the wet fall and winter of 1994-95. Serum samples collected from 462 wild pigs at 28 different sites were screened for exposure to brucellosis and pseudorabies. Preliminary results were that seropositive results for brucellosis were noted at only three sites, whereas no animals were confirmed seropositive for pseudorabies. Although analyses of these two diseases are continuing, test results for trichinellosis, toxoplasmosis, and sylvatic plague reinforce previous warnings to hunters and consumers that sanitary handling and cooking of wild swine meat are warranted.

KEY WORDS: feral pigs, *Sus scrofa*, mark-recapture, population estimation, home range, diseases, experimental design, wildlife management

Proc. 17th Vertebr. Pest Conf. (R.M. Timm & A.C. Crabb, Eds.) Published at Univ. of Calif., Davis. 1996.

INTRODUCTION

Wild pigs (*Sus scrofa*) are an introduced mammal in the United States where they presently occur in at least 20 states including California (Mayer and Brisbin 1991). Populations of wild pigs were first established in California around 1770 with the arrival of the Spanish (many domestic pigs that were released to forage in the oak woodlands around the early Spanish settlements became feral; Barrett and Pine 1980). Subsequent to their initial establishment, wild pigs have increased in number and expanded their range through both natural dispersal and numerous additional introductions by humans. Currently, wild pigs occur in at least 45 of 58 counties in California (Waithman 1995).

Although accurate estimates of population sizes are difficult to obtain, Clark et al. (1983) used annual hunter take survey information to estimate that there were approximately 80,000 wild pigs in California in 1983. However, little is known about the present number of pigs in California because of their high reproductive output (mature females can produce more than 10 piglets/year; Barrett 1978) and the resulting high rate of population growth. Also, pig populations fluctuate in response to changing environmental conditions because of weather-related variation in forage quantity and water availability (Schauss et al. 1990; Sterner 1990). Drought conditions may have severely limited pig numbers in the period from 1987 to 1991. More recently, substantial rainfall during the fall and winter of 1992-93 and 1994-95 has created substantial scope for the expansion of wild pig

populations due to the improved availability of forage and water.

In California, wild pigs are valued by hunters and private ranch lease hunt operations as an important big game species (Tietje and Barrett 1993). For example, from 1990 to 1993 approximately 30,000 wild pigs were taken annually by hunters from private lands and through paid recreation programs (Waithman 1995). However, other constituencies consider wild pigs pests because their rooting behavior can damage agricultural fields and natural areas (Kotanan 1995; Tietje and Barrett 1993). Related to these issues, wild pigs are often the focus of ecological studies and/or eradication efforts (Hone 1995; Katahira et al. 1993; Schauss et al. 1990; Sterner 1990; Baber and Coblenz 1986).

The disease status of wild pigs is another important consideration in their management because wild pig populations may serve as reservoirs of infection for domestic pig herds and/or humans. For example, wild pigs have been implicated as the source of infection of economically important diseases such as pseudorabies virus (PRV) in domestic pig herds. In California, disease surveys have documented serologic evidence of brucellosis and PRV in wild pigs in Monterey, Santa Clara, Tehama, and San Luis Obispo counties, and from San Clemente and Catalina Islands (Timm et al. 1994; Drew et al. 1992; Clark et al. 1983). From a human health perspective, the potential for exposure to zoonotic disease in those people with direct or indirect exposure to wild pigs is also of concern. Hunters and trappers may

receive intensive exposure to diseases in infected tissues and body fluids when field dressing wild pig carcasses. For example swine brucellosis can cause severe acute and chronic disease in humans, and hunters may be exposed when dressing wild pig carcasses and consuming meat from infected feral pigs (Bigler et al. 1977). Also, humans can contract trichinellosis, toxoplasmosis or sylvatic plague from consuming poorly cooked meat or by direct or indirect contact with wild pigs.

Wild pigs have been managed as a big game mammal in California since 1957. Associated with increasing human conflicts with expanding wild pig populations in the 1980s, management strategies for wild pigs are evolving by legislative mandate. Current wild pig management objectives are to maximize recreational opportunities for sportsmen while simultaneously reducing human conflicts with wild pigs through depredation programs (Waithman 1995). Effective management of wild pig populations depends on access to reliable information on their distribution and density throughout California. In 1994, a research group of biologists and veterinarians at the University of California, Davis undertook a study aimed at assessing population densities and disease status of wild pigs in California. The primary objective of the study was to develop techniques and methodologies useful for assessing current and future densities of wild pig populations. This information will be used by the California Department of Fish and Game (CDF&G) to develop and revise management strategies for wild pigs. In addition to conducting population research, wild pig populations were sampled and examined for the seroprevalence of selected zoonotic agents. The disease research is directed at updating and adding to the current knowledge on the distribution and prevalence of diseases such as brucellosis and PRV in wild pig populations. Information on zoonotic agents will

be used to assess the potential for disease transmission from wild pigs to domestic livestock and humans. In this paper, research protocols are detailed and the results briefly summarized of the population and disease research for 1994 and 1995.

STUDY SITES

Information on wild pig habitat associations and the relative densities of wild pig populations (e.g., hunter killed pig tag return data) was used to select areas for research. Permanent pig range in California includes oak woodland/thickets, oak woodland/grasslands, chaparral, and chaparral/grasslands around reliable water sources. Within these habitat types in northern California, data from hunter killed pig tags indicate that high density pig populations occur primarily in Tehama, Mendocino, and Sonoma counties. Less dense wild pig populations occur in Lake, Colusa and Napa counties. In central California, high density pig populations are focused in Santa Clara, San Benito, Monterey, and San Luis Obispo counties, less dense populations are focused in Santa Cruz, Stanislaus and Santa Barbara counties. In 1994, research was conducted at two sites in Sonoma county, and one site each in Mendocino, and Monterey counties (Table 1). Research was conducted in 1995 at one study site each in San Luis Obispo, Monterey, Santa Clara, Sonoma, Mendocino, and Colusa counties (Table 1). To assess potential changes in wild pig population sizes associated with variation in weather conditions between 1994 and 1995 (precipitation was low in 1994 and high in 1995), in 1995 the population studies were repeated at three of the four sites studied in 1994 (Table 1). In the disease survey research, wild pig serum samples were obtained from several additional sites described in the disease methodology section.

Table 1. U.C. Davis wild pig project population and disease research sites in California in 1994 and 1995.

Site Name	County	Trapping Period	Description
Lake Sonoma Park	Sonoma	May-June 1994	Army Corps of Engineers Reservoir
Bradford Ranch	Mendocino	June-July 1994	Private cattle ranch
Austin Creek SRA	Sonoma	August 1994	California State Park
Rancho San Carlos	Monterey	September-October 1994	Private ranch/land partnership
Chimney Rock Ranch	San Luis Obispo	May-June 1995	Private cattle ranch
Rancho San Carlos	Monterey	June 1995	Private ranch/land partnership
Henry Coe State Park	Santa Clara	July 1995	California State Park
Austin Creek SRA	Sonoma	August 1995	California State Park
Bradford Ranch	Mendocino	August-September 1995	Private cattle ranch
Salt Lake Ranch	Colusa	September 1995	Private cattle ranch

POPULATION RESEARCH STUDY DESIGN AND METHODS

Early in the project the feasibility, cost, and practicality of several different techniques for estimating wild pig population sizes and densities were reviewed. Based on this review, an experimental design was selected using mark-resight techniques to estimate local population sizes, which, in association with data on wild pig movements, could be used to estimate population densities.

The basic procedure in a mark-recapture study is to capture a number of animals from a population over a short time, mark and then release them, and recapture individuals to check for marks. Information on the proportion of marked animals in the second sample of recaptured individuals can be used to calculate population sizes. The mark-recapture technique is most effective when the initial sample and the sample of recaptured individuals are relatively unbiased with respect to the sex and age structure of the population being sampled. Also, the sample of recaptured animals should be unbiased relative to the original sample of marked animals. Previous studies of wild pigs suggest that adult male and possibly adult females are difficult to recapture (Baber and Coblenz 1986; Schauss et al. 1990). Because of this, automatically triggered camera systems were used to "recapture" pigs by resighting them in order to minimize biases associated with retrapping animals. Mark-resight techniques may be used for open or closed population situations. The wild pig research was designed to approximate a closed population model by resampling with camera systems within one month of the original marking period. Techniques used to estimate population sizes from resight data are detailed below.

Wild Pig Trapping

Modified panel traps were used to trap wild pigs (trap design described by Sweitzer et al., unpublished manuscript). At each study area an attempt was made to operate a minimum of three traps. Traps were geographically arranged to minimize overlap in trapping areas with respect to wild pig movements. Two factors that are known to influence wild pig trapping success are the selection of sites with recent pig activity and prebaiting of both the potential trap site and the trap itself (Choquenot et al. 1993; Saunders et al. 1993). Suitable trap sites were identified by surveying for evidence of recent wild pig activity (rooting, trails, wallows, and feces). Trap sites were prebaited with a mixture of fermented corn and meat scraps covered by an inverted 19 liter bucket weighted with a rock to secure it in place. Several small, uncovered bait piles were placed along transects at approximately 10 m intervals in the direction of areas of potential pig travel (along animal trails or drainages). Pre-bait stations were checked regularly until pig activity was detected on two to three successive nights, whereupon a trap was established.

Partial traps were initially set up to familiarize pigs with consuming bait in an enclosed area. After pigs consumed bait in the partial traps, complete traps were set up and baited. When pigs had fed inside complete traps for at least one night, traps were set for captures. Because wild pigs can overheat and die when exposed to

warm ambient temperatures (Baber and Coblenz 1986), traps were set at dusk and then checked and processing begun on animals one to two hours before dawn or late at night. Wild pigs were immobilized for processing using a combination of Telazol (3.3 mg/kg) and xylazine (1.65 mg/kg) as described by Sweitzer et al., unpublished manuscript).

Wild Pig Processing Protocol

Immobilized pigs were removed from traps and hobbled with nylon straps for processing. Samples and data collected during processing included: 1) 20 to 60 cc of blood by jugular venipuncture; 2) dental formulas for aging with Matschke's (1967) tooth eruption schedule; 3) chest circumference and mid-dorsal body length (base of the skull to the top of the tail); 4) body weight (± 1 kg); and 5) a sample of ectoparasites (five minute timed search).

All captured pigs were ear-tagged to facilitate identification in camera station photographs. Numbered yellow, orange, red, and white Allflex tags were attached to the ears of adult females, subadult females, adult males, and subadult males, respectively. California Department of Fish and Game tags were placed in the right ears of all animals. Two "ID photos" of individual pigs (one each from the left and right side of pigs) were taken to assist in identifying animals in the camera station photos.

Resight Techniques and Analyses

Pigs were resighted using photographs from Trailmaster camera systems (TM1500 Active Infrared Trail Monitors with TM35-1 Camera Kits, Goodson & Associates Inc., Lenexa, Kansas). In 1994, a minimum of one camera station per successful trap was used to resight wild pigs at each site. In 1995, two camera stations were used per successful trap to resight animals. Resight operations were conducted within one month of the trapping period at a site. Camera stations were located in areas with pig activity in the vicinity of trap sites (camera stations were generally not placed directly at trap sites). Suitable sites for camera stations were located, prebaited, and monitored for pig activity until trapping terminated, after which camera stations were constructed. The Trailmaster camera systems consisted of a 35 mm fully automatic camera with flash, and an active infrared trail monitor (transmitter and receiver). The Trailmaster system uses the obstruction of an infrared beam of light passing between a transmitter and a receiver to trigger a camera and photograph the animal(s) passing through the beam. The date and time of exposure are automatically recorded on each photograph. At camera stations, the transmitter and receivers were mounted on trees or 0.9 m fence posts approximately 5 to 6 m apart. The two units were mounted so that the light beam between the transmitter and receiver was 35 to 40 cm above ground level. Cameras (linked to the receiver by a cable), were mounted either above the receiving unit or they were offset such that both the receiver and transmitter were visible in the cameras field of view. Uncovered bait piles were placed along the light beam path and two bucket covered bait piles were placed on either side of the light beam.

Trailmaster camera systems can be programmed to take photographs during selected periods of the day. At all sites except Rancho San Carlos, wild pig activity was primarily nocturnal. Thus, camera stations were programmed to take photographs from dusk until dawn at all sites except Rancho San Carlos. At the Rancho San Carlos site wild pigs were more diurnal, camera stations were programmed to take photographs throughout the day. All camera stations were programmed for 5 to 10 minute time delays between photographs in order to obtain multiple photos of wild pig groups consuming bait. Camera stations were monitored and rebaited until at least two 36 exposure rolls of film were used. In general, a minimum of four nights was needed to obtain ≥ 72 photographs. On several occasions, however, camera stations were damaged by wild pigs or other animals. Damaged camera stations were either prematurely removed or repaired and operated for longer time periods.

Camera station photographs were examined for marked and unmarked wild pigs using an 8X pocket magnifier. Only one sighting of an individual was counted at a camera station each day. Multiple photographs of pigs visiting camera stations usually allowed for individual identification of tagged animals from ear tag colors and ID photographs. In cases where tagged animals to the individual could not be identified, sightings were scored as "unknown tagged." Photographs in which the ears of pigs were not visible prior to analyses were excluded.

A review of the literature on mark-recapture and mark-resight computer models was conducted to select the most appropriate model for analyzing the wild pig data. Program NOREMARK uses the Lincoln-Peterson model for closed populations to estimate population sizes from mark-resight data (White 1994). Neal et al. (1993) provide an evaluation of this computer model using data on mountain sheep (*Ovis canadensis canadensis*). Program NOREMARK offers four different estimators of population abundance and the Bowden estimator was used to analyze the resight data as suggested by White (pers. comm.).

Home Ranges and Density Estimates

Estimated population sizes were converted into densities by using home range data to estimate areas sampled by traps. Information on the home ranges of wild pigs was obtained from literature sources and from 18 wild pigs that were radiocollared during the research. Criteria used for selecting home range data from outside literature sources included: 1) home range data generated from radiocollared pigs; 2) home range information restricted primarily to summer-fall time periods (corresponding to the trapping period); and 3) home range data was for wild pigs from mainland or island systems in California.

Wild pigs that were radiocollared in the study were located a maximum of twice a day to approximate independence of positions. To minimize the influence of bait on wild pig movements, radiotracking was not conducted until after trapping and resight operations had ceased at the research sites. Wild pig locations were determined from visual observations or foom triangulation on compass bearings taken from known positions. A

Trimble Basic Plus geographical positioning system was used to determine map locations of both visual pig observations and positions used for triangulation. Triangulation was done on 7.5 minute USGS topographical maps. Estimates of the minimum convex polygon (MCP) home ranges of wild pigs were determined using a computer software program (RANGES IV, Kenward 1990).

Excluding data from wild pigs at Rancho San Carlos (see below and Table 2), the MCP home ranges from the wild pigs that were radiocollared were very similar to the home ranges of wild pigs from other studies (Table 2). Thus, an overall mean wild pig home range was computed to estimate the area sampled by traps at the research sites (Table 2). However, wild pigs at Rancho San Carlos (RSC) had oversized home ranges relative to animals tracked at other research sites (Table 2). This was potentially because the RSC wild pigs exhibited more Eurasian wild boar characteristics than wild pigs at other sites (RSC was the site for the original introductions of Eurasian wild boars into California in 1925). Because the home ranges of RSC wild pigs were larger than at the other sites, the mean home range size was used for the eight pigs radiocollared at that site for estimating areas sampled by traps there (Table 2).

When the minimum convex polygon home ranges of wild pigs was plotted over their initial capture locations, visual analyses indicated that pigs were often captured near the edges of their ranges. This suggested that baited traps attracted wild pigs from distances of around one home range diameter. Assuming that wild pig home ranges were approximately circular (verified by MCP home ranges), it was estimated that the area sampled by a pig trap was equal to the area of a circle with radius equal to the diameter of an average wild pig home range. Thus, the area sampled by a trap was estimated by the equation $A = \pi d^2$, where d is equal to the diameter of the average wild pig home range. The total area sampled by traps at each research site was determined by calculating the area enclosed by the circles around traps minus areas of overlap.

DISEASE INVESTIGATION METHODS

Serum samples were collected opportunistically from 462 wild pigs from December 1993 to October 1995. Blood samples were stored on ice and centrifuged for serum separation within 24 hours of collection. After separation, serum samples were frozen or stored on ice until they could be transported to the University of California, Davis (UC Davis) for storage (samples were stored at -80°C until analyzed). Serologic testing was conducted by the California Veterinary Diagnostic Laboratory System (CVDLS) in Davis and Fresno, California. Serology for trichinellosis, toxoplasmosis, and plague for 69 animals sampled during 1994 was performed in the laboratory of Dr. Bruno Chomel at the UC Davis. Laboratory examination of the samples collected in 1995 for trichinellosis, toxoplasmosis, and sylvatic plague have not been completed.

Specimens were screened for evidence of exposure to *Brucella* sp. using the buffered acid plate agglutination (BAPA) test, the CARD test, or both, and were interpreted as either positive or negative. The rivanol test

Table 2. Home range estimates (km²) for wild pigs in the coastal regions and islands of California. Mean wild pig home range *without* Rancho San Carlos wild boars = 2.44 (SD = 1.65, N = 31). Mean home range for Rancho San Carlos wild boars = 7.35 (SD = 4.10, N = 8).

Research Site	N	Home Range Size (km ²)	Source
Lake Sonoma Recreation Area, Sonoma County	2	1.97 ± 0.13	This study, 1994
The Bradford Ranch, Mendocino County	1	2.86	This study, 1994
Austin Creek SRA, Sonoma County	3	3.33 ± 2.23	This study, 1994
Rancho San Carlos, Monterey County	8	7.35 ± 4.10	This study, 1994
Henry Coe State Park, Monterey County	4	1.72 ± 0.71	This study, 1994
Almaden Quicksilver Park, Santa Clara County	5	2.33 ± 1.82	Schauss, 1988
Grant Park - Mt. Hamilton, Santa Clara County	3	3.11 ± 0.95	Schauss, 1980
Calaveras & San Antonio Reservoir, Santa Clara & Alameda Counties	2	2.35 ± 0.35	Schauss, 1992
Santa Cruz Island, Santa Barbara County	10	2.49 ± 1.98	Sterner, 1990
Dye Creek Ranch, Tehama County	1	1.47	Grover, 1983

was used to confirm the results of positive tests. A specimen was considered suspect if either or both of the BAPA or Card tests were positive and seropositive only if the rivanol titer was greater than or equal to 1:25. The enzyme linked immunosorbent assay (ELISA) and/or latex agglutination (LA) tests were used to screen for exposure to PRV. Confirmation was by serum virus neutralization test (SVN). Statistical analyses were performed using Epi-info version 6. Due to small sample sizes and missing cell values, the Fishers' exact test was used to determine significant differences between groups and sampling sites.

POPULATION RESEARCH RESULTS

In 1994 and 1995 a total of 233 wild pigs were captured during research on wild pig populations at seven different sites (three of the seven sites were visited in both years). Trailmaster camera stations were effective for resighting wild pigs; a total of 3,192 photographs of wild pigs was obtained from 53 different camera stations for population size analyses. Resulting mark-resight data and MCP home range data were used to estimate population sizes and densities at each of the study sites.

Lake Sonoma

Lake Sonoma was the first site for research in 1994. Six wild pigs were captured in one successful trap with no recaptures over 10 trap nights (trap success = 0.6 pigs/trap night). Three of the six animals captured were radiocollared (Table 2). Two pigs were collared for estimating home range sizes and a third was collared because of a potentially lethal injury sustained upon capture (broken nasal bones). The injured pig was closely monitored via radiotelemetry and recovered. Three camera stations were used to resight pigs. Photos of wild pigs were obtained at two of the three sites. However,

because of limited success resighting pigs at the Lake Sonoma camera stations, observations of wild pigs noted during research activities were used to augment resight data. Using these data, the estimated population size for the 9.73 km² area trapped was 12 wild pigs for a density of 1.2 pigs/km² (95% C.I. range of 0.6 to 2.6 pigs/km²).

Bradford Ranch

Research was conducted at the Bradford Ranch in both 1994 and 1995. In 1994 eight wild pigs were captured in three modified panel traps and dogs and dart rifles were used to capture an additional two pigs. One animal was radiocollared here in 1994 (Table 2). Including recaptures, 14 wild pigs were captured over 16 trap nights at the Bradford Ranch in 1994 (Trap success = 0.88 pig/trap night). Three camera stations were used in resight efforts in 1994. Mark-resight data indicated that the estimated population size within the approximately 13.81 km² area trapped was 14 pigs for a density of 1.0 pigs/km² (95% C.I. range of 0.9 to 1.3 wild pigs/km²). In 1995, 10 different wild pigs were captured in two traps at the Bradford Ranch. No animals were recaptured and the trap success over nine trap nights was 1.1 pigs/trap night. Five camera stations were used for mark-resight efforts in 1995. The estimated population size for the 14.53 km² area trapped was 17 wild pigs for a density of 1.2 pigs/km² (95% C.I. range of 1.0 to 1.3 wild pigs/km²). One of the ten animals captured in 1994 was recaptured in 1995 and three others were observed at camera stations. Although the same number of animals was captured in both years, the estimated density of increased by approximately 16% from 1994 to 1995.

Salt Lake Ranch

Research was conducted at the Salt Lake Ranch in 1995 (Table 1). Twenty-two different wild pigs in three

traps at the site were captured. Including recaptures, 25 pigs were captured over 10 trap nights (trap success = 2.5 pigs/trap night). Four camera stations were used for mark-efforts. The estimated population size for the 24.81 km² area trapped was 44 wild pigs for a density of 1.8 pigs/km² (95% C.I. range of 1.5 to 2.2 wild pigs/km²).

Austin Creek State Recreation Area

Research was conducted at Austin Creek SRA in both 1994 and 1995 (Table 1). In 1994, 15 wild pigs were captured in three traps. Including recaptures, a total of 24 pigs were captured over 17 trap nights (trap success = 1.4 pigs/night) and three pigs were radiocollared to estimate home ranges (Table 2). Three camera stations were used for mark-resight efforts in 1994. The estimated population size within the 21.58 km² area trapped was 29 pigs for a density of 1.3 pigs/km² (95% confidence interval range of 1.0 to 1.7 pigs/km²).

In 1995, twenty-four wild pigs were captured in three traps at Austin Creek SRA. Including recaptures, 35 pigs were captured over 16 trap nights (trap success = 2.2 pigs/trap night). Six camera stations were used for mark-resight efforts in 1995. The estimated population size for the 21.58 km² area trapped was 45 wild pigs for a density of 2.1 pigs/km² (95% C.I. range of 1.8 to 2.5 wild pigs/km²). Of the 15 wild pigs captured at this site in 1994, three were recaptured and a fourth was noted at camera stations in 1995. More wild pigs were captured at the site in 1995 than in 1994. Most importantly, however, the estimated population density increased by approximately 56% from 1994 to 1995.

Henry Coe State Park

Research was conducted at Henry Coe State Park in 1995 (Table 1). Fifty-five different wild pigs were captured in five traps at the site. Including recaptures, 81 pigs were captured over 20 trap nights (trap success = 4.1 pigs/trap night). Four wild pigs were radiocollared at Henry Coe State Park and their mean home range was 1.72 ± 0.71 km² (Table 2). Ten camera stations were used for mark-resight efforts. The estimated population size for the 29.19 km² area trapped was 97 wild pigs for a density of 3.3 pigs/km² (95% C.I. range of 2.8 to 3.9 wild pigs/km²).

Rancho San Carlos

Research was conducted at Rancho San Carlos (RSC) in both 1994 and 1995. In 1994, 54 wild pigs were captured in six traps. Including recaptures, 122 pigs were captured during 30 trap nights (trap success = 4.1 pigs/night). Eight pigs were radiocollared at the site. Seven camera stations were used for mark-resight efforts. The estimated population size within the 54.50 km² area trapped was 67 pigs for a density of 1.2 pigs/km² (95% C.I. range of 1.1 to 1.4 pigs/km²).

In 1995, 28 different wild pigs were captured in six traps at the site. Including recaptures, 36 pigs were captured over 21 trap nights (trap success = 1.7 pigs/trap night). Nine camera stations were used for mark-resight efforts. The estimated population size for the 64.9 km² area trapped was 112 wild pigs for a density of 1.7 pigs/km² (95% C.I. range of 1.2 to 2.4 wild pigs/km²). Fewer pigs were captured at the site in 1995 than in 1994.

Also, although many of the pigs that were marked in 1994 in 1995 were observed, none of the 1994 animals were recaptured. Although the 95% confidence intervals were wide for 1995, the estimated density increased by approximately 41% from 1994 to 1995.

Chimney Rock Ranch

Research was conducted at the Chimney Rock Ranch in 1995 (Table 1). Eleven pigs were captured in two successful traps at the site over seven trap nights (trap success = 1.6 pigs/trap night). Four camera stations were used for mark-resight efforts. The estimated population size for the 19.46 km² area trapped was 37 wild pigs for an estimated density of 1.90 pigs/km² (95% C.I. range of 0.87 to 4.16 wild pigs/km²).

DISEASE INVESTIGATION RESULTS

Blood samples from 69 animals sampled in 1994 were screened for exposure to brucellosis, PRV, trichinellosis, sylvatic plague, and toxoplasmosis. Overall, two animals tested positive for trichinellosis at two different sites, five animals tested positive for plague (all at Rancho San Carlos), and eight animals tested positive for toxoplasmosis (one each at Lake Sonoma and Bradford Ranch and three each at Austin Creek and Rancho San Carlos). There were no differences in the seroprevalence of trichinellosis or toxoplasmosis among the different sex and age classes of wild pigs, or for pigs among study sites. For sylvatic plague, however, location and age group significantly affected seroprevalence results. Higher exposure to sylvatic plague was found at Rancho San Carlos in Monterey county compared to the other three research sites. In analyses with animals from all age categories included, the seroprevalence of sylvatic plague was marginally higher at Rancho San Carlos than at the other three research sites combined (Fisher exact 1-tailed p-value = 0.045). Because exposure to diseases may be a function of age (older animals have an increased duration of disease exposure), the data was partitioned and examined seroprevalence in adults only. For mature adults, the seroprevalence for sylvatic plague was higher at Rancho San Carlos than at the other three research sites combined (Fisher exact 1-tailed p-value 0.002).

Four hundred sixty-two samples collected at 28 different sites during 1994 and 1995 were screened for exposure to brucellosis and PRV. Fourteen wild pigs from three sites tested positive for brucellosis and no animals were confirmed positive for PRV. Additional analyses of these data will be presented elsewhere.

DISCUSSION

Wild Pig Trapping

Success at trapping wild pigs was contingent on surveys for pig sign, pre-baiting at potential trap sites, and free-baiting traps prior to captures. Trap success at Lake Sonoma was low because of limited pre-baiting and poor initial trap design (Sweitzer et al., unpublished manuscript). With the standard surveying and baiting protocols, trapping success averaged a relatively high 2.4 pigs/trap night. In Santa Clara County, California, for example, Schauss et al. (1990) used box traps and noted an average trap success of 3.2 pigs/trap night during the summer months. Two different wild pig studies in

Australia reported trap successes of 1.0 and 2.0 pigs/trap night using square panel traps (Choquenot et al. 1993; Saunders et al. 1993). In general, it was possible to move to prebait, and capture and mark animals within three weeks.

Mark-Resight Techniques

Trailmaster camera stations were effective at resighting marked pigs for population estimation. Although some camera stations were placed along trails in areas with pig activity, sighting pigs when stations were pre-baited and set-up in the vicinity of pig wallows was most successful. Using two camera stations for each successful trap in order to enhance resight coverage and enhance the precision of population estimates is recommended. With prebaited camera station sites and 5 to 10 minute camera delays, it was possible to run through two 36 exposure rolls of film in less than seven days.

Wild Pig Populations

In the 1994 population research, wild pig densities were uniformly low across all four sites (mean density = 1.21 wild pigs/km²). Low population densities in 1994 may have been the combined result of low precipitation and poor acorn crops in the fall and winter of 1993-94. When landowners, hunters, and resource managers were questioned, for example, nearly all thought that pig populations had declined in 1994 because of these factors. By contrast, after near-record precipitation in the fall and winter of 1994-95, population densities were 16% to 56% higher at the three sites where population research was repeated. These results suggest that wild pig populations in central and northern California increased in response to the increased availability of forage after the wet fall and winter of 1994-95. How the availability of acorns in fall 1994 may have interacted with weather conditions to enhance the growth of the different populations has not been examined. For example, wild pig densities increased proportionally more at Austin Creek SRA than at Rancho San Carlos and the Bradford Ranch, potentially related to regional variation in acorn production in fall 1994. Hunting pressure may also affect wild pig population densities. In 1995, for example, wild pig densities were highest at Austin Creek SRA and Henry Coe State Park where hunting is not allowed. Preliminary comparisons of minimum population sizes from camera station sightings with the mark-resight estimates suggest that the computer program NOREMARK underestimated wild pig population sizes. This potential bias will be investigated further and other mark-recapture microcomputer programs will be investigated for their accuracy in predicting population sizes using camera station sighting data.

DISEASE INVESTIGATIONS

Preliminary results from the disease research suggest that wild pig populations have low prevalences of brucellosis and PRV. Serum samples collected from 462 wild pigs at 28 different sites were screened for exposure to brucellosis and PRV. Seropositive results for brucellosis were noted at only three sites, whereas no wild pigs were confirmed seropositive for PRV. Although few

wild pigs were seropositive for brucellosis, the infected herds were nonrandomly distributed and the seroprevalence in the infected herds was relatively high. Also, the disease results do not preclude the presence of PRV in areas not well sampled, and analyses of the brucellosis and PRV data are continuing. Seropositive test results for Trichinellosis (2.9%) and toxoplasmosis (11.6%) reinforce the previous warnings to hunters, butchers, and consumers that sanitary handling and thorough cooking of meat from feral swine are warranted.

The disease data on sylvatic plague from the four 1994 study sites were compatible with the known spatial distribution of the disease agent in California (Jay and Chomel 1994). The probability of exposure to plague appears to be greater in mature adults than in piglets and juveniles. As with other diseases, this is probably at least partly a function of the increased duration of exposure for adults. Clark et al. (1983) suggested that wild pigs may be a better sentinel species than coyotes or black bear for monitoring sylvatic plague, since hunting is conducted all year long. These assumptions require further testing through continued research on feral swine in California.

CONCLUSIONS AND FUTURE RESEARCH

In this paper, methods and preliminary results from two years of research were detailed on wild pig populations in California. Although the wild pig trapping and mark-resight techniques are effective at providing information on wild pig populations, the authors are working on a less labor intensive approach to estimate densities that may be more useful for management. Initial indications are that it is possible to individually identify unmarked pigs from camera station photographs. This is important because it may be possible to use automatic camera stations to gather population information on wild pigs without trapping and immobilizing the animals to mark them. Use of this camera station technique, however, will need to be validated using population estimates from more traditional mark-resight methodologies.

ACKNOWLEDGMENTS

The authors would like to especially acknowledge and thank the numerous ranch owners and resource managers for granting access to the research sites. Merle Griffith, Jim Swanson, Renee Pasquinelli, Dale Haskins, and Kay Robinson were very helpful with providing research access to Lake Sonoma Recreation Area, Austin Creek State Recreation Area and Henry Coe State Park, respectively. Jeffrey Froke—The Rancho San Carlos Partnership, Pete Bradford, Hy Blythe, Ralph Stegall, Lud and Bud McCrary, Kevin Piper and Brenda Smith, and George Work graciously granted the field team access to Rancho San Carlos, the Bradford Ranch, the Chimney Rock Ranch, the Salt Lake Ranch, the Big Creek Ranch, the Swanton Pacific Ranch, and the Work Ranch, respectively. The authors also thank the many people who contributed to the collection of additional wild pig blood samples for the disease studies including Henry Coletto, Joe Didenado, Maureen Farr, Mark Morrison, and Bert Claassen. Bill Clark and Bob Mapes of the California Department of Fish and Game provided financial, logistic, and technical support. Bill Clark,

Victor Velez (California Department of Food and Agriculture) and Tony Grissom (Bestor Engineers) provided valuable technical support to the project. Research funds were provided by grants from the California Department of Fish and Game, and the USDA, APHIS, Veterinary Services. Finally, the research could not have been completed without field help by Marcus Doherr, George Ghneim, John Drew, Bob Hilberg, Paul Brandy, Lisa Shender, and Amy Brinkhouse.

LITERATURE CITED

- BABER, D. W., and B. E. COBLENTZ. 1986. Density, home range, habitat use, and reproduction in feral pigs on Santa Catalina Island. *J. Mammal.*, 67:512-525.
- BARRETT, R. H. 1978. The feral hog on Dye Creek Ranch, California. *Hilgardia* 46:283-355.
- BARRETT, R. H., and D. S. PINE. 1980. History of wild pigs, *Sus Scrofa*, in San Benito County, California. *Cal. Fish and Game* 67:103-117.
- BIGLER, W. J., G. L. HOFF, W. H. HEMMERT, J. A. TOMAS, and H. T. JANOWSKI. 1977. Trends of brucellosis in Florida. *Am. J. of Epidem.*, 105: 245-251.
- CHOQUENOT, D., R. J. KILGOUR, and B. S. LUKINS. 1993. An evaluation of feral pig trapping. *Wildl. Res.*, 20:15-22.
- CLARK, R. K., D. A. JESSUP, and D. W. HIRD. 1983. Serologic survey of California wild hogs for antibodies against selected zoonotic disease agents. *J. Am. Vet. Med. Assoc.*, 183:1248- 1251.
- DREW, M. L., D. A. JESSUP, A. A. BURR, and C. E. FRONTI. 1992. Serologic survey for brucellosis in feral swine, wild ruminants and black bear of California, 1977 to 1989. *J. Wildl. Dis.*, 28:355-362.
- KOTANEN, P. M. 1995. Responses of vegetation to a changing regime of disturbance: effects of feral pigs in a Californian coastal prairie. *Ecography* 18:190-199.
- GROVER, M. A. 1983. The home range, habitat utilization, group behavior, and food habits of feral hog (*Sus scrofa*) in northern California. M. S. Thesis, California State University, Sacramento. 75 pp.
- HONE J. 1995. Spatial and temporal aspects of vertebrate pest damage with emphasis on feral pigs. *J. Appl. Ecology* 32:311-319.
- JAY, M. T., and B. B. CHOMEL. 1994. Public health implications of feline plague. *Cal. Vet.* May-June 10-12.
- KATAHIRA, L. K., P. FINNEGAN, and C. P. STONE. 1993. Eradicating feral pigs in montane mesic habitat at Hawaii Volcanoes National Park. *Wildl. Soc. Bull.* 21:269-274.
- KENWARD, R. 1990. RANGES IV: software for analyzing animal location data. Wareham, United Kingdom. 33 pp.
- MATSCHKE, G. H. 1967. Aging European wild boar by dentition. *J. Wildl. Manage.*, 31:109-113.
- MAYER, J. M., and I. L. BRISBIN. 1991. Wild pigs in the United States: their history, comparative morphology, and current status. University of Georgia Press, Athens, Georgia. 31 pp.
- NEAL, A. K., G. C. WHITE, R. B. GILL, D. F. REED, and J. H. OLTERMAN. 1993. Evaluation of mark-resight model assumptions for estimating mountain sheep numbers. *J. Wildl. Manage.*, 57:436-450.
- SAUNDERS, G., B. KAY, and J. NICOL. 1993. Factors affecting bait uptake and trapping success for feral pigs (*Sus scrofa*) in Kosciusko National Park. *Wildl. Res.*, 20:653-65.
- SCHAUSS, M. E. 1980. Population dynamics and movements of wild pigs in Grant Park. M.S. Thesis, San Jose State University, California.
- _____. 1988. Movements and population characteristics of wild pigs in Almaden Quicksilver County Park. Research report, Santa Clara County Parks and Recreation Department. 35 pp.
- _____. 1992. San Francisco water department wild pig survey: Calaveras and San Antonio reservoir watersheds. Research report, San Francisco Water Department. 63 pp.
- SCHAUSS, M. E., H. J. COLETTI, and J. J. KUTILEK. 1990. Population characteristics of wild pigs (*Sus scrofa*), in eastern Santa Clara county, California. *Cal. Fish and Game* 76:68-77.
- STERNER, J. D. 1990. Population characteristics, home range, and habitat use of feral pigs on Santa Cruz Island, California. M.S. Thesis, University of California, Berkeley.
- TIETJE, W., and R. H. BARRETT. 1983. The wild pig in California oak woodland: ecology and economics. Symposium proceedings, University of California, Berkeley.
- TIMM, S. F., J. S. ROMSOS, D. K. GARCELON. 1994. Serologic survey for pseudorabies virus, brucellosis and San Miguel sea lion virus in an isolated population of wild pigs (*Sus scrofa*). Unpubl. report, Institute for Wildlife Studies. Arcata, California.
- WAITHMAN, J. D. 1995. Wild pig management plan for California. Draft report, California Department of Fish and Game.
- WHITE, G. C. 1994. Program NOREMARK software reference manual. Colorado State University. 35 pp.