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Author
Sweitzer, Rick A.

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CONSERVATION IMPLICATIONS OF FERAL PIGS IN ISLAND AND MAINLAND ECOSYSTEMS, AND A CASE STUDY OF FERAL PIG EXPANSION IN CALIFORNIA

RICK A. SWEITZER, Department of Wildlife, Fisheries, and Conservation Biology, University of California, Davis, California 95616.

ABSTRACT: Feral pigs (*Sus scrofa*) are an exotic ungulate which have been widely introduced worldwide with multiple ecosystem and economic consequences. The author conducted a semi-comprehensive literature review directed at identifying the current state of knowledge related to the effects of feral pigs on island and mainland plant and animal communities. Also, the author describes the situation in California where feral pigs that were introduced in the late 1700s are now widespread due to hunting-related introductions and natural range extensions. Feral pigs on predator-free oceanic islands are a serious conservation problem because they attain high densities and have contributed to near-extinctions and extinctions of multiple endemic plants and vertebrates. In mainland ecosystems, however, feral pigs can have both positive and negative effects depending on the local circumstances. Rooting, for example, can have both positive and negative effects on growth and survival of some trees, soils and soil processes, and the distribution of native and exotic grasses. In general, however, the negative effects of rooting by feral pigs are amplified when population densities are high. Feral pigs may compete with native species for limited resources, but there are limited data relevant to this hypothesis. Based on observations of small amounts of animal matter in their diets, feral pigs eat terrestrial vertebrates and eggs of ground nesting birds, but the importance of predation by feral pigs on native vertebrates is poorly known. Feral pigs also may have important indirect effects in mainland ecosystems by providing a new prey base for native predators which may then increase. In areas of Europe with extant wolf (*Canis lupus*) populations, wild boar (*Sus scrofa*) are an important prey species which may be facilitating numerical and geographic recoveries of wolves. Because wild boar are important prey for endangered Amur tigers (*Panthera tigris*), they are considered important for recovering tiger populations. In Australia, feral pigs are potentially important prey for dingoes (*Canis familiaris dingo*); whereas, in the United States, endangered Florida panthers (*Felis concolor coryi*) consumed 23% to 59% feral pigs, and mountain lions (*Felis concolor*) in Texas and California consumed 5% to 38% feral pigs. Research needs for feral pigs include quantitatively assessing: 1) how acorn foraging by feral pigs limits or influences regeneration of oaks (*Quercus* sp.); 2) the competitive effects of feral pigs on native species; 3) whether direct predation by feral pigs suppresses small vertebrate populations; and 4) how the availability of feral pigs as prey influences native predator populations.

KEY WORDS: *Sus scrofa*, predation, competition, rooting effects, distribution, California

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INTRODUCTION

The introduction of exotic species to new regions has generated much concern among conservationists and agriculturalists, because exotics can disrupt ecosystems and cause significant economic losses (Hone 1995; Morrison and Williams 1997). Once some exotics become established, they are difficult to eradicate except in small, localized regions or in island situations (Parkes 1990). In cases where it is not economically or logistically feasible to eradicate introduced species, it becomes necessary to focus management and conservation efforts on minimizing the ecosystem effects and economic damage by the organisms (Hobbs and Huenneke 1992).

Pigs (*Sus scrofa*) are a large ungulate native to Eurasia and North Africa which are now widely distributed as feral animals. Currently, wild pigs (wild boar or feral pigs) are found on all continents except Antarctica. The non-native distribution of wild pigs encompasses parts of North and South America, Central America, Australia, New Zealand, New Guinea, South Africa, and many oceanic islands (Kotanen 1995). Where populations of feral pigs are established, they can have important ecosystem and economic consequences. Ecosystem effects of feral pigs are related to the animals vigorously grubbing in wet or moist soil in search of acorns, plant bulbs/tubers, and small invertebrates (rooting), and direct predation. Negative economic effects of feral pigs result from the exploitation of row crops in agricultural fields by populations living in adjacent natural areas (Giusti 1993). Feral pigs in Australia also are important predators on domestic sheep (Choquenot et al. 1996).

Wild pigs are an extremely adaptable and generalized omnivore with a high reproductive output (two litters of five to six piglets per year) (Mauget 1991) and wide climatic tolerances (Lloyd et al. 1987). These characteristics result in feral pigs being very difficult to eradicate except on small islands or enclosed areas (Barrett et al. 1988; Katahira et al. 1993). Thus, in several countries where feral pigs are particularly numerous (Australia, New Zealand, United States), management efforts are directed at reducing, and then maintaining relatively low, wild pig densities in order to minimize their negative effects on ecosystems and agricultural areas (McIlroy et al. 1989; Choquenot et al. 1993). Although range expansion by feral pigs in some areas has ceased because of habitat limitations or intensive control programs (Clarke and Dzieciolowski 1991), the range extent of feral pigs in other areas continues to increase. In California, for example, feral pigs have recently expanded in distribution (Sweitzer et al. 1997a).

The author's objectives in this paper are threefold. First, to review the current state of knowledge related to the ecosystem-level effects of feral pigs to facilitate identifying key areas where additional research is needed. Second, to examine predator-prey relations among wild boar and their predators because very little is known of the implications of feral pigs as prey for native predators in Eurasia, and review what is known concerning predator-prey relations among feral pigs and several large predators in Australia and North America. Information on predator-prey relations involving feral pigs is important because increased prey availability may result in increased predator populations, thereby contributing to increased depredation on domestic livestock. Third, and finally, to describe aspects of the range expansion of feral pigs in mainland regions of California as a case study of management issues with the species.

METHODS

The author conducted a semi-comprehensive review of the scientific literature to identify the current state of knowledge on the potential effects of feral pigs on ecosystem properties. Undocumented statements regarding the multiple negative effects of feral pigs are found in many published accounts of feral pig biology. Thus, included in the review are only those studies which attempted to quantitatively examine different aspects of the effects of feral pigs on plant or animal communities. The author initially planned to include only peer-reviewed papers published in the scientific literature in the study. However, when reviewing proceedings from several symposia and some documents in the grey literature, useful information from several well-designed studies was found and included.

Data on range expansion dynamics for feral pigs in mainland California were drawn primarily from studies by Sweitzer et al. (1997a). Sweitzer et al. (1997a) used combined information from annual Hunter Game Take Surveys and hunter-killed wild pig tag returns to track range expansion by feral pigs and to delineate their distribution in mainland regions of California. Feral pigs also were introduced to the Channel Islands off the coast of southern California. The author compiled information on the history of feral pig introductions to the Channel Islands and described the extent and success of eradication efforts to subsequently remove the animals.

EFFECTS OF FERAL PIGS ON ISLAND ECOSYSTEMS

Feral pigs occur on many oceanic islands where their population densities frequently attain very high levels compared to mainland populations. On the Channel Islands of California, for example, feral pig densities commonly exceed 20 pigs/km^2 (Baber and Coblentz 1986; Sterner 1990) compared to on the nearby and ecologically similar mainland where densities of 3 to 4 pigs/km^2 are exceptional (Sweitzer et al. 1997a). On oceanic islands feral pigs have contributed to declines and extinctions or near-extinctions of endemic plants (Kastdalen 1982; Campbell and Rudge 1984; Challies 1975; Ralph and Maxwell 1984), seabirds (Stone and Scott 1984; Cruz and Cruz 1987), iguanid lizards (*Conolophus subcristatus*), giant tortoises (*Geochelone elephantopus*), and green sea turtles (*Chelonia mydas*) (McFarland et al. 1974; Green 1981). There were no studies that reported unequivocal positive effects of feral pigs on islands.

EFFECTS OF FERAL PIGS ON MAINLAND ECOSYSTEMS

The literature review revealed that numerous studies have examined issues related to rooting effects of feral pigs on mainland vegetation and plant communities, some have assessed changes in soil properties associated with rooting, but very few have directly examined issues related to interspecifiic resource competition, effects of acorn foraging on oak regeneration, or predation by feral pigs on native vertebrates. Below, the author describes the approximate state of knowledge related to these multiple potential effects of feral pigs.

Rooting Effects on Mainlands

In mainland situations the effects of rooting by feral pigs are variable and can sometimes positively influence ecosystems. Rooting by feral pigs on steep slopes may increase erosion (Schauss 1992), but on gentler slopes it can increase filtration and mobilize soil nutrients (Lacki and Lancia 1983; Singer et al. 1984). Rooting may reduce cover of herbaceous plants and shrubs and limit tree regeneration (Howe et al. 1981; Alexiou 1983; Bratton 1975; Lipscomb 1989; Becker 1985; deNevers and Goatcher 1990; Vtorov 1993), but can also enhance the growth of some trees (Lacki and Lancia 1986). Rooting in some areas has enhanced the spread of exotic grasses (Hone and Stone 1989; Spatz and Mueller-Dombois 1975; Vtorov 1993), but other research suggests it may increase the proportion of native annual and perennial plants (Aplet et al. 1991; Kotanen 1995; Lacki and Lancia 1983). Rooting may or may not alter or eliminate microhabitats for small rodents and amphibians (Singer et al. 1984; Lusk et al. 1993), and little is known of how this effects vertebrate populations. Also, it has been suggested by Work (1993) that rooting by feral pigs in California is ecologically equivalent to historically intensive rooting by grizzly bears (*Ursus arctos*) because of similarities in the appearance of grasslands and meadows rooted by the two species (Mattson 1997; Tardiff et al. 1997). Grizzly bears, which were historically widespread and very abundant in oak woodland habitats in California, were extirpated by the late 1900s. Ongoing research in Glacier National Park, Montana suggests that bear diggings in alpine meadows are qualitatively similar to rooting by feral pigs in wet meadows; grizzly bears repeatedly disturbed some areas, and plots disturbed by bears contained more plant species than undisturbed plots (Tardiff et al. 1997). Although the effects of feral pigs on mainlands varies, it is generally true that the negative effects of rooting are greatest when densities are high, which may explain the pronounced effects of feral pigs on islands.

Feral Pigs and Interspecific Competition

Feral pigs may have important effects on mainland ecosystems by diverting limited resources from native species (Barrett 1982). In Australia, for example, feral pigs root in mesic sclerophyll forests where they consume fruit bodies of hypogeous fungi (Claridge and May 1994). This is significant because fungal fruit bodies are a key resource for the endangered northern bettongs (*Bettongia tropica*). Laurance (1997) found that densities of northern bettongs were negatively correlated with feral pig rooting damage in wet sclerophyll forests, indicating that feral pigs are either in competition for fungal fruit bodies with northern bettongs, or northern bettongs avoid habitats damaged by rooting. Wherever acorn mast crops are available, feral pigs consume considerable amounts of the resource (Bratton 1975; Schauss et al. 1990; Bruinderink and Hazebroek 1996). It has long been considered that feral pigs compete with multiple species by consuming acorns and other mast crops (Barrett 1982), however, no studies have yet examined the hypothesis. In the oak woodlands of California, populations of feral pigs are strongly influenced by annual variation in mast production (Sterner 1990; Schaûss et al. 1990). Although feral pigs consume considerable acorn mast, one alternative hypothesis is that feral pigs now consume a resource previously used by grizzly bears (Work 1993). In the 1800s, for example, grizzly bears were often observed in small groups beneath oak trees consuming acorns. Native Indians also harvested and consumed significant acorn mast. The extent to which feral pigs compete with native species for acorns, or whether they simply consume acorn mast previously used by other consumers remains unknown.

Feral Pigs as Predators

As generalized omnivores feral pigs are hypothesized to prey directly on reptiles, amphibians, and the eggs of ground-nesting birds (Henry 1969; deNevers 1993). Many diet studies reveal that feral pigs consume relatively low proportions of animal matter in their diets (Everitt and Alaniz 1980; Taylor and Hellgren 1997). However, reptiles and amphibians are occasionally observed in the stomachs of pigs (deNevers 1993), which they probably encounter when rooting in leaf litter or overturning ground debris. Systematic studies are needed to assess the importance of feral pig predation on regionally declining amphibian populations. Several studies have examined egg predation by feral pigs. Henry (1969) found that feral pigs "were a very minor nest predator" on eggs placed in dummy nests. Tolleson et al. (1993) noted that feral pigs will opportunistically consume eggs of ground-nesting birds, but it was not known if mortality was additive. In Australia, feral pigs may occasionally consume eggs from nests of the large, flightless Cassowary (*Casuarius casuarius*), an endangered ground-dwelling ratite (Crome and Moore 1990). Cassowaries have been in considerable decline due to loss of wet forest habitats in Australia. Research is needed to determine whether egg predation by feral pigs further threatens this endangered bird species (Crome and Moore 1990).

FERAL PIGS AS PREY FOR PREDATORS

Although a great deal of research has focused on the rooting effects of feral pigs, little is known of how the availability of feral pigs as prey may influence predator populations. This is important, ecologically, because predators can strongly influence prey populations by regulating population sizes and altering community structure (Mills and Shenk 1992; Estes 1996). Also, predators are of economic importance because they prey on domestic livestock and pets (Giusti et al. 1990; Bangs and Fritts 1996; Torres et al. 1996). The availability of feral pigs as prey may alter predator-prey systems and have a cascade of unanticipated indirect effects. For example, predator-prey theory predicts that generalist predators will switch to alternative prey (functional response) when the density of their primary prey declines (Taylor 1984). Because the functional response can stabilize or lead to increases in predator populations (numerical response), the introduction of alternative prey to an ecosystem may have large impact on predator populations in a region and, thus, a large effect on the ecosystem as a whole. In this section the author reviews what is known regarding wild boar and feral pigs as prey for predators to gain insight into how predator populations may respond to the availability of feral pigs.

Predator-prey Relations Among Eurasian Wild Boar and Their Natural Predators

Eurasian wild boar are an important prey species for extant wolf (*Canis lupus*) populations in Europe. Although wolves were historically widespread in Europe, they declined to extinction in most of the western and southern part of the continent by the end of the 19th century because of persecution and reduced availability of large ungulate prey (Okarma 1995); remnant populations of wolves remained in a few mountainous areas or isolated refugia in Spain, Italy, Poland, Asia and north and eastern Europe. In the last 20 to 30 years wolf populations in Europe have experienced numerical and geographical recoveries; in the early 1990s wolves expanded back into France from Italy (Poulle et al. 1997). With the exceptions of wild boar and roe deer (*Capreolus capreolus*), distributions of large forest ungulates in Europe [red deer/elk (*Cervus elaphus*), bison (*Bison bonasus*), moose (*Alces alces*)] decreased significantly due to habitat loss/conversion and hunting pressure (Okarma 1995). The current distribution of wild boar includes most of the species' historical range, as well as range extensions in parts of northern Europe (Saez-Royuela and Telleria 1986; Okarma 1995). Wild boar adapted well to agricultural development as evidenced by 70% to 90% crops (potatoes, grain, maize) in their diets when they occupy forest fragments adjacent to agricultural areas (Okarma 1995). The contemporary distribution of wolves in Europe overlaps completely with the contemporary range of wild boar. Diet studies from France, Italy, and Poland reveal that wild boar account for 7% to 53% of prey biomass for wolves depending on the availability of other wild and domestic prey (Mattiolo et al. 1995; Meriggi et al. 1996; Okarma 1995). Based on the consistent occurrence and importance of wild boar in wolves' diets, wild boar were probably important for maintaining viable wolf populations when they were in decline and may have facilitated recent recovery of wolves in parts of Europe. Also, in some areas of Italy, wolves prey heavily on livestock (Meriggi et al. 1996). Thus, one indirect effect of the availability of wild boar as prey for wolves in Europe may be increased predation by wolves on domestic livestock.

In a study of the endangered Amur tiger (*Panthera tigris*) in Russia, Miquelle et al. (1996) reported that elk and wild boar were key components of tigers' diets, together accounting for 84% of tiger kills. Wild boar individually were 20% of tigers' diets. Miquelle et al. (1996) recognized the importance of populations of forest ungulates for the conservation of the endangered Amur tiger and recommended that management programs actively work to maintain habitats and populations of wild boar and elk.

Feral Pigs as Prey for Dingoes in Australia

The dingo (*Canis familiaris*) is a widespread and common native predator in Australia where bounty programs are used to minimize predation by dingoes on livestock (Woodall 1983). In areas of Australia where feral pigs are uncommon, dingoes prey on kangaroos (*Macropus* sp.) rabbits (*Oryctolagus cuniculus*), and livestock (Thomson 1992). However, in Queensland, Australia where feral pigs are abundant and widespread, Woodall (1983) reported that feral pigs were important prey for dingoes. An index to dingo and feral pig populations based on bounty totals indicated that dingo populations closely tracked those of feral pigs and that feral pig numbers expanded and increased in local areas when dingo numbers were reduced (Woodall 1983). The author found no other published information discussing the importance of feral pigs to dingo populations in other areas of Australia.

Feral Pigs as Prey for Felids in North America

Feral pigs are now widespread in the southeastern United States, Texas, and California (Wood and Barrett 1979; Mayer and Brisbin 1991) where they co-occur with coyotes (*Canis latrans*), black bears (*Ursus americanus*), bobcats (*Lynx rufus*), and mountain lions. Of these potential predators of feral pigs, mountain lions may be the most important. Recent research has identified the importance of feral pigs as prey for the endangered Florida panther (*Felis concolor coryi*). Maehr et al. (1990) reported that Florida panthers consumed up to 59% feral pigs where panthers co-occurred with abundant feral pigs. Feral pigs in Florida were considered so important as prey for panthers that the feasibility of releasing feral pigs into the interior of the home ranges of individual panthers to augment their prey base was assessed (Maehr et al. 1989).

Research in Texas and California indicates that mountain lions prey on feral pigs in regions where feral pigs are abundant. Based on predator-kills and scat samples, Harveson (1997) determined that feral pigs constituted 28% to 32% of the diets of mountain lions in southern Texas.

Several studies in the Central Coast region of California indicated that mountain lions consumed 5% to 38% feral pig in their diets depending on the season (reviewed by Hopkins 1989). There are no quantitative data relating the availability and consumption of feral pigs by mountain lions to the dynamics of mountain lion populations in California. However, there is some evidence for a relation between expanding feral pigs and increasing mountain lion densities based on mountain lion depredations on livestock (Dick 1995; Torres et al. 1996) and Annual Hunter Game Take Survey data for feral pigs (Sweitzer et al. 1997a; CDFG unpublished data). Since 1972 when records on mountain lion depredation incidences begin, lion predation on domestic livestock has gradually and then more rapidly increased. Based on analyses of Annual Hunter Game Take Survey data, feral pigs expanded significantly over the same time period (Figure 1). A correlational analysis of the county level expansion by feral pigs and increasing numbers of mountain lion depredation permits issued by CDFG for counties in which feral pigs were present revealed a positive and significant correlational relation between expanding feral pigs and increasing mountain lion depredation incidences (Figure 1; Pearson correlation coefficient = 0.95, Bartlett's c^2 statistic = 20.08, d.f. = 1, $P < 0.001$).

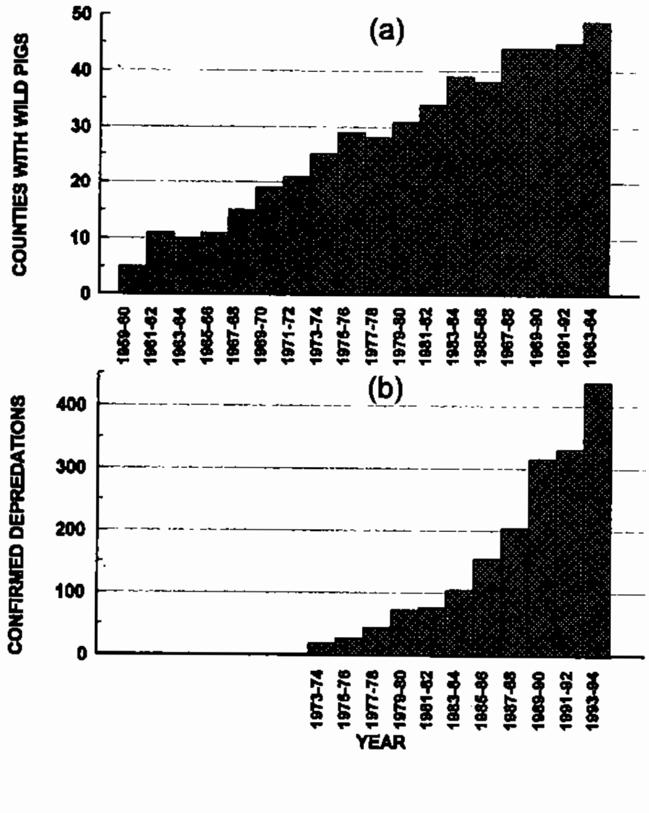

Figure 1. County level range expansion by feral pigs during sequential two year periods from 1959 to 1994 (a), and confirmed mountain lion depredation incidences from 1973 to 1994 (b). Numbers of mountain lion depredation incidences were included only for those counties in which feral pigs were considered present (hunted during at least one year during each two year period) during the same two year period.

Also, preliminary data from work by the research group directed at reconstructing diets of mountain lions based on concentrations of stable isotopes of carbon and nitrogen in the tissues of lions and their prey (see Ben-David et al. 1997 for details) suggest that several mountain lions in the North Coast region of California (where wild pig densities are >2.0 per km^2) included around 45% feral pigs in their diets (Figure 2). Based on increasing predation by mountain lions on livestock and increased frequencies of human-lion encounters, it has been suggested that mountain lion populations are increasing in some parts of California (Torres et al. 1996). It is not known yet whether this phenomena is directly related to the expanding and increasing number of feral pigs.

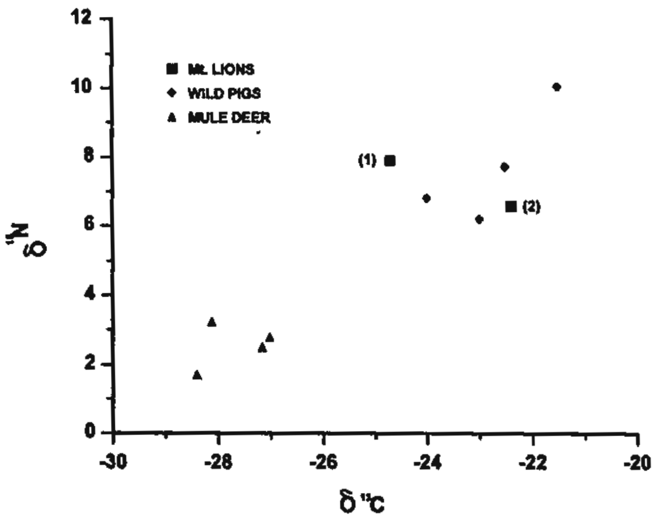

Figure 2. Values for $\delta^{13}C$ and $\delta^{15}N$ from preliminary analyses of muscle tissue of mountain lions, wild pigs, and mule deer from the North Coast region of California. Stable isotope signatures of wild pigs and mule deer are significantly different in bivariate space ($P < 0.001$ K nearest-neighbor randomization test; Rosing et al. 1998). Stable isotope values suggest that mountain lion 1 consumed 31% wild pig and 69% mule deer; whereas, mountain lion 2 consumed 43% wild pig and 57% mule deer, based on isotope ratios of wild pigs and mule deer and fractionation processes analyzed in a multi-source mixing model (Ben-David 1997b).

CASE HISTORY OF RANGE EXPANSION BY FERAL PIGS IN CALIFORNIA

The history of feral pigs in California begins with Spanish exploration and settlement in the 1600s and 1700s. Feral pigs were introduced to many of California's Channel Islands, but have been successfully eradicated from several of the islands in recent years. Feral pigs in mainland California have spread significantly since first being introduced. Due to the rugged topography, dense forests, and thick vegetation characteristic of feral pig habitats, however, eradication of feral pigs from extensive areas on California's mainland will probably be impossible. Below the author details the history of feral pigs on the Channel Islands and mainland of California, including details on disease and management considerations not already discussed.

Feral Pigs on the Channel Islands of California

Historically, no large native grazing animals occurred on the Channel Islands off the coast of southern California. Several ungulates including feral pigs were introduced to the four largest islands in the Channel Island archipelago (Santa Cruz, Santa Catalina, Santa Rosa, San Clemente) historically. The earliest introduction dates are poorly known, but feral pigs were established on Santa Cruz and Santa Rosa Islands by the 1700s, associated with Spanish explorations and a Spanish penal colony (Mayer and Brisbin 1991). Feral pigs were introduced to both Santa Catalina and San Clemente Islands in the early 1900s (Mayer and Brisbin 1991). Multiple efforts have subsequently been undertaken to reduce the impact of feral animal populations on the ecosystems of Santa Cruz and Santa Catalina Islands. Feral pigs were successfully eradicated from San Clemente and Santa Rosa Islands in 1980s and early 1990s, respectively (Long 1993). Several attempts to eradicate feral pigs from Santa Cruz and Santa Catalina Islands have so far proven unsuccessful (Sterner and Barrett 1991; Garcelon et al. 1993). However, an intensive eradication program from 1995 to 1997 successfully removed nearly all of the feral pigs from a 38 km^2 fenced area of the western portion of Santa Catalina Island (Garcelon, pers. comm.) Feral pigs are opportunistically killed on Santa Cruz Island but no organized eradication programs are underway there.

Feral Pigs in Mainland California

Feral pigs were first established in coastal regions of California in the 1700s from domestic stock free-ranged to forage in oak woodlands around early Spanish settlements (Barrett 1978; Pine and Gerdes 1973). Subsequently, Eurasian wild boar that were released in Monterey County in 1925 spread and interbred with the already present feral pigs to produce hybrid feral pig-Eurasian wild boar populations (Hoehne 1994). Although feral pigs were well established in California in the 1800s, their range extent was limited to fewer than 10 counties in coastal regions until the 1950s (Mayer and Brisbin 1991). In 1956, however, feral pigs were officially designated a game mammal whereupon numerous ranchers and landowners introduced them to their properties to establish populations desirable for fee-hunting (Barrett 1993). Multiple hunting-related introductions combined with natural dispersal has precipitated significant recent expansion by feral pigs. By the early 1980s, some 80,000 feral pigs had expanded to over 30 of California's 58 counties (Mansfield 1986), and in 1996, approximately 133,000 feral pigs occupied parts of 49 counties (Sweitzer et al. 1997a). Because feral pigs are adaptable and appear to be expanding into habitats/areas not previously considered suitable, feral pigs may continue to expand and increase in some parts of California where population densities are currently low (Sweitzer et. al. 1997a).

Hybridization between already present feral pigs and landowner-introduced Eurasian wild boar type feral pigs in some parts of the state in the 1950s and 1960s may have contributed to the accelerated post-1950s expansion of feral pigs. Due to hybrid vigor, hybridized Eurasian wild boar-feral pig type feral pigs may have experienced enhanced adaptive abilities which allowed them to expand into less suitable habitats. Little is known about the population genetics of feral pigs in California, but the author is currently using mitochondrial DNA techniques and analyses to examine this hypothesis.

Livestock and Zoonotic Diseases of Feral Pigs in California

Sweitzer et al. (1997a) screened multiple populations of feral pigs in California for a variety of livestock and zoonotic diseases. Results from their work suggest there are relatively few areas in California where moderate to high density feral pig populations overlap with important domestic swine producing areas. Also, no confirmed evidence of pseudorabies, and isolated instances of brucellosis exposure, suggest that feral pigs pose relatively low risks for infecting domestic swine with these important livestock diseases (Sweitzer et al. 1997a). Feral pigs in mainland California do harbor several zoonotic diseases (trichinosis, toxoplasmosis, leptospirosis, sylvatic plague) (Clark et al. 1983; Sweitzer et al. 1996), indicating that hunters should take necessary precautions when field-dressing animals to minimize exposure to blood. Also, and of potential importance for public health, Atwill et al. (1997) reported that feral pigs shed both *Cryptosporidia parvum* oocysts and *Giardia* sp. cysts in their feces. To the extent that these two microorganisms in feral pig feces are directly deposited or carried into municipal water supplies by overland flow, feral pigs may pose a risk of causing gastrointestinal illness among immune-suppressed individuals who drink from contaminated water supplies (Atwill et al. 1997). Additional and more widespread screening of feral pigs for livestock and zoonotic disease will help refine our knowledge of disease risks associated with feral pigs in California.

Management of Feral Pigs in California

The recent range expansion and increased levels of rooting damage caused by feral pigs has led to acrimonious debate regarding the management status of the species. The principal management objective of CDFG for feral pigs has been to control populations by hunting while simultaneously allowing landowners to remove feral pigs causing property damage after obtaining permits (Waithman 1995). However, some constituencies feel that feral pigs are a pest and should be subject to removal without special permit arrangements (Tietje and Barrett 1993). Related to these issues, Sweitzer et al. (1997a) noted that hunting may be effective in controlling feral pig densities on public and private lands in California where hunting pressure is high. However, feral pig numbers can be very high in unhunted parks or on private lands/ranches with limited hunter access. The result of localized regions with high densities of feral pigs has been increasing human-wild pig conflicts, debate over the efficacy of hunting to manage feral pigs, and calls to abolish already liberal hunting regulations to facilitate attempts to eradicate feral pigs. In another paper presented at this 18th Vertebrate Pest Conference, Doug Updike reviews changing management approaches with feral pig populations related to recently enacted legislation making it easier for landowners and others to remove feral pigs causing damage to private property, agriculture, and natural areas.

SUMMARY

Feral pigs on islands have multiple negative effects on plant and animal communities and should be eradicated whenever possible. In mainland situations, feral pigs can have both positive and negative effects depending on population densities. Future research on the rooting effects of feral pigs should focus primarily in regions where population densities are highest. Very little is currently known about the effects of feral pigs as competitors or predators. Additional research is needed in these areas, particularly where feral pigs overlap with threatened or endangered plants and animals. Finally, because predators can have important ecosystem and economic effects, research examining the significance of feral pigs as prey for native predators will help determine whether expanding feral pigs are contributing to increased predator densities and higher levels of livestock predation. Also, high numbers of predators supported by feral pigs may prey on native prey species at unusually high rates, thereby precipitating declines among those species (Sweitzer et al 1997b).

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