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Conservation of the Island Spotted Skunk and Island Fox in a Recovering Island Ecosystem

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Abstract. We review available information on the ecology of island spotted skunks (*Spilogale gracilis amphiala*) and island foxes (*Urocyon littoralis santacruzae*) on Santa Cruz Island, with a focus on recent research, and present new information on distribution and abundance. Our objective is to evaluate the present and future status of skunks and foxes in the context of ongoing island recovery following removal of nonnative herbivores. Overall, foxes are abundant on Santa Cruz Island and display a wide range of resource use. They are habitat generalists, do not use permanent dens, are active both day and night, and have an omnivorous diet of mice, insects, and fruits. In comparison, spotted skunks are relatively rare and are resource specialists. They are more specialized in their habitat use, utilize excavated dens, are nocturnal, and have a carnivorous diet of primarily mice and insects. We suggest that island foxes, because they are more ecologically generalized than skunks, may initially benefit more from island recovery and are less susceptible to impacts of the rapidly expanding feral pig population on the island. The relatively specialized resource use of spotted skunks, coupled with their low population sizes and relatively narrow geographical range, increases both their susceptibility to environmental perturbations and their relative vulnerability of extinction.

Keywords: Santa Cruz Island; California Channel Islands; island spotted skunk; island fox; insular endemic carnivore; resource use; nonnative species; feral sheep; feral pigs.

Introduction

Species diversity on islands is typically lower than comparable areas of the mainland (MacArthur and Wilson 1967). Consistent with this pattern, Santa Cruz Island, largest of the California Channel Islands, possesses a depauperate and unbalanced vertebrate fauna (Wenner and Johnson 1980). Despite its relatively large size (25,000 ha), the island supports only 4 native species of non-volant, terrestrial mammals: the island spotted skunk (*Spilogale gracilis amphiala*), the island fox (*Urocyon littoralis santacruzae*), the deer mouse (*Peromyscus maniculatus santacruzae*), and the harvest mouse (*Reithrodontomys megalotis longicaudus*) (von Bloeker 1967; but see Collins and George 1990).

Little is known about the ecological relations of endemic mammalian carnivores on islands because they do not usually occur on islands (Williamson 1981; Brown and Gibson 1983). Santa Cruz Island is, therefore, unusual in that it supports not 1, but 2 species of similar-sized, endemic mammalian carnivores, the island spotted skunk and the island fox.

Insular ecosystems and the species they support are particularly sensitive to disturbance by nonnative species (Vitousek 1988; Coblentz 1990; Primack 1993). Detrimental effects of biological invasions on islands serve to increase extinction rates of insular endemics, rates already high due to small populations, narrow ranges, and low genetic diversity (Vitousek 1988). Unfortunately, Santa Cruz Island is no exception to the biological invasions so prevalent on islands. Long-term overgrazing by feral sheep, as well as domestic cattle, has resulted in severe environmental degradation on the island (Van Vuren and Coblentz 1987, 1989; Brumbaugh 1980; Hobbs 1980; Minnich 1980). Because of this damage, nearly 38,000 sheep were removed from the island in the early 1980s (Schuyler in press). Cattle were removed when the island's ranching operation was discontinued in 1988.

Removal of nonnative herbivores from islands is highly desirable because of the severe damage they cause to island ecosystems (Van Vuren and Coblentz 1987; Bratton 1988; Coblentz 1990); dramatic recovery of insular plant communities typically results (Hamann 1979; Meurk 1982; Scowcroft and Giffin 1983). Recovery, however, may not always lead to the full restoration of original communities. Release from grazing pressure may favor the spread of undesirable nonnative plants that can outcompete endemic species (Taylor 1968; Scowcroft 1987). Further, recovery of plant communities may improve habitat quality for nonnative animals, such as feral pigs (*Sus scrofa*), that themselves cause damage to island resources (Van Vuren 1981).

Removal of feral sheep and domestic cattle from Santa Cruz Island has resulted in obvious and dramatic recovery of island vegetation. Not all recovery, however, has involved endemic species. In particular, fennel (*Foeniculum vulgare*) has increased in both density and distribution (see Beatty and Licari 1992), presumably because of release from grazing pressure. Additionally, regrowth of vegetation, as expected, has been paralleled by a substantial increase in numbers of feral pigs, an increase that has been further stimulated by the recent end of a prolonged drought. Feral pigs can have extreme impacts on sensitive insular ecosystems (Oliver 1984; Van Vuren 1984; Anderson and Stone 1993).

Conservation of the island spotted skunk and island fox is important for the state of California; the island fox is listed as a threatened species and the island spotted skunk is listed as a subspecies of special concern. Santa Cruz Island is experiencing major ecological changes following the removal of nonnative herbivores, but effects of these changes on the skunk and fox are unknown. Regrowth of vegetation in general, and the spread of nonnative plants such as fennel in particular, likely will affect habitat quality for skunks and foxes. Effects may be positive or negative. Further, the increase in feral pigs may have several impacts, all negative: pigs may cause habitat degradation by rooting, they may compete with skunks and foxes for food, and they may even prey upon juveniles of either species.

In this paper we review available information on the ecology of island spotted skunks and island foxes on Santa Cruz Island, with a focus on recent research, and present new information on distribution and abundance. Our objective is to evaluate the present and future status of skunks and foxes in the context of ongoing island recovery following removal of nonnative herbivores.

Ecology of Island Spotted Skunks and Island Foxes

Study area

Santa Cruz Island is located 40 km south of Santa Barbara. A system of interior valleys, including the large Central Valley, is oriented in an east-west direction and bounded by mountain ranges on the north (maximum elevation 750 m) and the south (465 m).

Santa Cruz Island supports the greatest diversity of indigenous plant taxa (420) of any of the California Channel Islands (Raven 1967). Ten different plant communities on the island have been described (Philbrick and Haller 1977), and Minnich (1980) reported that grassland, chaparral, coastal sage scrub, and oak-woodland covered 89% of the island. In addition to these community classifications, Crooks (1994a) designated areas dominated by a mixture of chaparral shrubs and open grassy areas as chaparral-grasslands, and designated grasslands dominated by fennel as fennel-grasslands.

History of skunks and foxes

The island spotted skunk, a subspecies of the western spotted skunk (*S. gracilis*), has a shorter tail and broader face than its mainland counterpart (Van Gelder 1959, 1965). Skunks are restricted to the 2 largest of the California Channel Islands, Santa Cruz and Santa Rosa, but are thought to have occurred on San Miguel Island until the late nineteenth century (Walker 1980; Williams 1986). Although the date of origin of spotted skunks on the Channel Islands is unknown, skunk remains in Native American Chumash archeological sites on Santa Cruz Island reveal that skunks at least pre-date the arrival of Europeans (R. Colton 1993, pers. comm.)

The island fox is about one-half to two-thirds the size of its mainland cousin, the grey fox (*U. cinereoargenteus*) (Wayne et al. 1991; Crooks 1994b). Island foxes occur on the 6 largest of the 8 California Channel Islands. They are thought to have first arrived on the northern Channel Islands at least 16,000 yr ago. Foxes, therefore, pre-date the arrival of the Chumash, who colonized the islands approximately 9,000 to 10,000 yr ago and who subsequently transported foxes to the southern islands (Gilbert et al. 1990; Collins 1991; Wayne et al. 1991).

Distribution and abundance

Foxes on Santa Cruz Island are both abundant and easily captured. Foxes on the island have higher population densities (7.9 km^{-2}, Laughrin 1980) than do grey foxes on the mainland (1.2–2.1 km^{-2}, Errington 1933; Gier 1948; Lord 1961; Trapp 1978). Likewise, relative abundance and trappability, as measured by trap success (individuals captured per trap nights x 100), is higher for island foxes (67%, Laughrin 1980; 23%, Crooks 1994b) than for mainland grey foxes (1–2%, Lord 1961). Although Crooks (1994b) recorded a lower trap success for island foxes than did Laughrin (1980), this does not necessarily indicate a population decline since trapping design differed between the studies. Laughrin (1980), as well as Lord (1961), set trap lines along roads or trails at set intervals (0.2 and 0.1 mi, respectively). Crooks (1994b), however, concentrated traps in areas likely to capture skunks as well as foxes and, therefore, likely reduced both the total number of foxes captured and the overall trap success.

Foxes occur throughout Santa Cruz Island and in all major habitat types (Laughrin 1980). To estimate relative abundance and distribution of skunks and foxes, in 1992 we placed track plate stations in each of the major plant communities on the island: grassland, chaparral, coastal sage scrub, and oak-woodland. Each station consisted of a bait lure surrounded by 2, 1-m x 1-m plates covered with a fine coating of diatomaceous earth. Stations were left in the same plot for 3 successive nights and were checked and reset daily. Distinguishable fox footprints were found in 41 out of the 46 total stations (89%) in all habitat types sampled.

Abundance of foxes, however, varies with habitat type and may be related to habitat productivity. Laughrin (1977) encountered foxes more often in oak-woodland than in grassland habitats. Interestingly, however, we found in 1992 that fennel-grasslands on the northeast side of the island yielded a higher overall trap success (34%) than did the chaparral-grasslands (10%) typifying much of the Central Valley.

Conversely, spotted skunks on Santa Cruz Island are relatively rare, difficult to capture, or both. Trap success was less than 1% for skunks on Santa Cruz Island (Crooks 1994b). Further, distinguishable skunk footprints were identified on track plates in only 1 out of 46 total stations (2%), in a coastal sage scrub community.

Although skunks are apparently uncommon on Santa Cruz Island, their distribution seems widespread. Information on skunk distribution, in addition to a relatively few trapped skunks in several locales, primarily consists of anecdotal reports of sightings, smells, tracks, and skunk remains (L. Laughrin 1992, pers. comm.) Skunks have been reported throughout the island, including the west end (Forney's Cove, Christy Ranch, Sauces Canyon), the southern coast (Laguna Canyon, Coches Prietos Canyon), the northern coast (Prisoners Harbor, Cañada del Porta), the east end (Rancho del Norte, the Navy Station, Scorpion Anchorage), and along the Central Valley (Centinela, the University of California Field Station, The Nature Conservancy Ranch, Valley Anchorage).

Habitat use

Habitat use of skunks and foxes on Santa Cruz Island was evaluated with radio-telemetry in 2 study areas (Crooks 1994a). One area, consisting primarily of fennel-grasslands, was located at Rancho del Norte on the northeast side of the island. The other area, consisting primarily of chaparral-grasslands, was located in the Central Valley north of the University of California (UC) field station.

Results indicate that skunks are more specialized than foxes in their habitat use. At the UC Field Station, most skunk radio-locations were in chaparral-grasslands and open grasslands, whereas foxes were habitat generalists and were located throughout the study area in all habitat types. Similarly, foxes at Rancho del Norte preferred fennel-grasslands, the most common habitat type, whereas skunks preferred ravines, a relatively uncommon habitat in the area. This preference by skunks for ravines is interesting considering that ravines in this area have slopes dominated by coastal sage scrub, and that this habitat is the only plant community on the island where we found skunk footprints on track plates. Therefore, skunks, in general, may frequent coastal sage scrub habitats on the island.

Den site selection

In our radio-telemetry study on foxes we found that foxes do not use permanent dens. Laughrin (1977) likewise reported that foxes do not use established dens but rather use any available sheltered site as a resting place. Spotted skunks, however, do excavate dens and do so in a variety of substrates, including the roots and earth under shrubs, cavities in rocks, open grassy areas, road cuts, human-made structures, and trunks and roots of oaks (Crooks 1994c). Individual skunks use several dens distributed throughout their home ranges; some dens are used by more than 1 skunk (Crooks 1994c).

Activity patterns

Radio-collared spotted skunks are nocturnal, with activity beginning around dusk and continuing on and off until dawn (Crooks 1994a). In contrast, foxes, as indicated by both radio-telemetry and visual observations, are active both day and night (Laughrin 1977; Fausett 1982; Crooks 1994a). Indeed, island foxes are more diurnal than mainland gray foxes, which are most active at night and relatively sedentary during the day (Fritzell 1987).

Diets

Island spotted skunks are more carnivorous, thus more specialized in their diets, than are island foxes (Crooks 1994a). Skunks eat primarily deer mice and insects; commonly eaten insects include jerusalem crickets, grasshoppers, beetles, and caterpillars. Lizards are also eaten relatively frequently by skunks.

In comparison, foxes are more generalized in their diets, utilizing a wide range of food items (Laughrin 1977; Crooks 1994a). Like skunks, foxes consume a variety of insect prey. Foxes also eat deer mice, although to a lesser extent than do skunks. Seasonally available fruits, however, totally absent from skunk diets, constitute a substantial portion of the fox's diet. Commonly eaten berries include toyon (*Heteromeles arbutifolia*), manzanita (*Arctstaphylos* spp.), prickly pear (*Opuntia* spp.), and summer holly (*Comarostaphylos diversifolia*).

Home range

Island foxes and island spotted skunks have similar-sized and overlapping home ranges (Crooks 1994a). Based on radio-telemetry, home-range size of radio-collared skunks averaged 21 ha, while home-range size of foxes averaged 18–22 ha, depending on season (Crooks 1994a). Previous estimates of home range size of foxes were ca. 32 ha based on trapping (Laughrin 1977) and ca. 20–40 ha based on radio-telemetry (Fausett 1982).

The similarity in home range sizes of skunks and foxes is surprising considering that skunks are substantial-

ly smaller in body size than foxes (Crooks 1994b) and that home range scales with body size in carnivores (Harestad and Bunnell 1979; Lindstedt et al. 1986; Swihart et al. 1988). Using body size allometries given in these studies, we calculated that fox home ranges should be anywhere from 3 to 6 times larger than skunk home ranges.

The similar home range sizes of skunks and foxes may relate to the relative resource use of the 2 species. Foxes are generalists and, therefore, might be able to find abundant resources in a relatively small area. Skunks, however, are more specialized and might require larger ranges to acquire sufficient resources. For instance, skunks at Rancho del Norte traveled substantial distances across grassland areas to reach ravines, perhaps to find necessary den sites or prey items. Indeed, differing diets between the 2 species may influence their relative home range sizes; carnivores like the skunk, with larger proportions of meat in their diet, require larger home ranges to meet their metabolic needs than do carnivores like the fox, which eat proportionately more fruits and insects (Gittleman and Harvey 1982).

Discussion

Overall, foxes are abundant on Santa Cruz Island and display a wide range of resource use. They are habitat generalists, do not use permanent dens, are active both day and night, and have an omnivorous diet of mice, insects, and seasonally available fruits.

Interestingly, fox densities, as indicated by relative trap success, appear to be higher in areas dominated by fennel-grasslands than in the chaparral-grassland areas typifying much of the Central Valley of the island. Indeed, radio-collared foxes at Rancho del Norte preferred fennel-grasslands, the most common habitat type of the area. Fennel likely provides excellent cover, travel routes, and resting sites for foxes. The Nature Conservancy, owners of most of Santa Cruz Island, is currently devising techniques to remove fennel from grassland communities on the island. Although fennel eradication is important in the recovery program for the island, 1 potential cost might be lower habitat quality for foxes in some areas. As we have demonstrated, however, foxes on Santa Cruz Island are not rare and are opportunistic in their habitat use. Consequently, removal of fennel may affect fox densities somewhat, but it likely presents little threat to the overall status of the fox population on the island.

As compared to foxes, skunks are relatively rare and are resource specialists. They are somewhat more specialized in their habitat use, utilize excavated dens, are active only at night, and have a carnivorous diet of primarily mice and insects. Differential resource use between skunks and foxes apparently creates sufficient ecological separation to allow for their coexistence. Nevertheless, resource overlap between skunks and foxes suggests some degree of interspecific competition between these 2 sympatric carnivores (Crooks 1994a).

Specifically, a generalist species may be at a competitive advantage when its broad niche overlaps the narrow niche of a sympatric competitor (see DeBach 1966; Hockman and Chapman 1983; Dibello et al. 1990). Competition between the 2 species, therefore, may have a greater effect on skunks than on foxes. Further, generalist species, like the fox, tend to be favored in disturbed ecosystems such as that on Santa Cruz Island (Hockman and Chapman 1983). Hence, although both species may occupy newly recovering areas of the island, island foxes, with a wider range of resource use, might initially benefit more from the island recovery. In the long term, however, skunks, since they are likely more sensitive to current disturbances on the island, may benefit more as these disturbed areas recover.

The relatively specialized resource use of the spotted skunk may also increase their susceptibility to the detrimental impacts of the rapidly expanding feral pig population on the island. The substantial habitat damage caused by feral pigs likely poses the most immediate threat to both skunks and foxes. Habitat disturbances might particularly affect skunks, however, since they are more specialized in their habitat use and are already relatively rare. Further, skunks, unlike foxes, require excavated dens as daytime resting sites. Extensive pig rooting, sometimes covering whole hillsides, may disturb existing skunk dens and make such areas unsuitable denning habitat. Rooting in areas with skunk dens also may increase the vulnerability of young skunks in dens to predation by pigs. Newborn foxes are exposed to a similar risk. Although we recorded no such predation events, pigs in other locales are known to feed opportunistically on a variety of vertebrate species (MacFarland et al. 1974; Wood and Barrett 1979; Miller and Mulette 1985; Coblentz and Baber 1987).

Pigs also may compete with both skunks and foxes for food. On Santa Catalina Island, feral pigs ate considerable amounts of fruits, including prickly pear, toyon, and manzanita, as well as smaller proportions of invertebrate prey (Baber and Coblentz 1987). The diet of pigs, therefore, overlaps that of both skunks and foxes, thus suggesting potential resource competition between the species. The relatively specialized diet of the spotted skunk again may increase sensitivity to such competition.

Overall, island fox populations on the 6 islands on which they occur are generally considered stable (Laughrin 1980; Gustafson 1991). Nevertheless, their small numbers and limited distribution relative to mainland species, as well as recent evidence of lack of genetic variability and susceptibility to canine diseases (Gilbert et al. 1990; George and Wayne 1991; Wayne et al. 1991; Garcelon et al. 1992), support their classification as threatened by the California Department of Fish and Game.

The island spotted skunk, however, occurs on only 2 of the Channel Islands, Santa Cruz and Santa Rosa, and

appears to be relatively rare on Santa Cruz Island. We suggest that, in comparison with island foxes, island spotted skunks may be particularly sensitive to environmental disturbances due to their relatively specialized resource use. Their apparently low densities and narrow geographical range may further increase their relative vulnerability to extinction. Certainly, evidence from recent studies (Pimm et al. 1988; Soulé et al. 1988), surveys (Terborgh and Winter 1980; Diamond 1984), and theoretical investigations (Leigh 1981; Belovsky 1987; Goodman 1987) indicates that population density is a primary factor in determining a population's risk of extinction.

The island spotted skunk has been classified only as a subspecies of special concern by the state of California, perhaps in part because its status and ecology were completely unknown. Our findings indicate that the continued existence of the island spotted skunk is precarious, more so than the island fox. We recommend further monitoring of population status and suggest that the island spotted skunk should be considered for reclassification as a threatened subspecies.

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