SPATIAL USE PATTERNS AND MANAGEMENT RECOMMENDATIONS FOR TWO ENDEMIC CALIFORNIA CHANNEL ISLAND MESOCARNIVORES, THE ISLAND SPOTTED SKUNK (*SPILOGALE GRACILIS AMPHIALA*) AND ISLAND FOX (*UROCYON LITTORALIS*)

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ABSTRACT

SPATIAL USE PATTERNS AND MANAGEMENT RECOMMENDATIONS FOR TWO ENDEMIC CALIFORNIA CHANNEL ISLAND MESOCARNIVORES, THE ISLAND SPOTTED SKUNK (*SPILOGALE GRACILIS AMPHIALA*) AND ISLAND FOX (*UROCYON LITTORALIS*)

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On the California Channel Islands, the island fox (*Urocyon littoralis*) has been hypothesized to compete with the smaller-bodied island spotted skunk (*Spilogale gracilis amphiala*). Recent declines in spotted skunk captures have raised concerns about the long-term survival of spotted skunks and the potential role of foxes in the decline. From 2018-2019, I GPS and VHF collared foxes and spotted skunks living on Santa Cruz Island to assess patterns of space use and deployed remote cameras to determine the potential for interaction between the two species at spotted skunk den sites. I found spotted skunk seasonal home ranges (HR) were approximately five times larger than previously reported, with spotted skunks utilizing only 32% of their seasonal HR in one week, while foxes moved widely, covering 60% of their seasonal HR during one week. Selection for vegetation types varied among individuals, within species and across locations on the island. When averaged across all animals, mean slope and vegetation cover at GPS points did not differ between foxes and spotted skunks, however, within two pairs inhabiting similar parts of the island, at least one of those parameters did differ, with spotted skunks using significantly denser cover in one instance and significantly steeper sites in the other. Camera trapping at den sites showed no relationship between fox visitation at spotted

skunk dens and the vegetation cover or slope at den sites. Photographic evidence of a fox attempting to dig an adult spotted skunk from its den suggest predation at den sites could be a factor in spotted skunk mortality.

Lastly, I provide management recommendations for monitoring spotted skunks on Santa Cruz Island in light of the current decline based on the results of several pilot studies. Results indicate current fox monitoring grids may not be an adequate method of detection for spotted skunks and I suggest future surveys include areas with a combination of high slope or high vegetation cover. I found that cameras placed in drainage bottoms may be more effective in detecting spotted skunks compared to ones placed on ridge tops. I also discourage the use of scents as a way to attract spotted skunks to camera stations as repeated marking by foxes may be a deterrent to spotted skunks. Finally, continued camera monitoring at spotted skunk den sites may provide valuable information on spotted skunk activity and abundance throughout the year.

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PREFACE

Chapter 1 of this thesis is formatted for the submission to the wildlife journal Southwestern Naturalist. My committee members will be listed as co-authors therefore throughout the chapter the pronoun “we” is used instead of “I.” Chapter 2 is intended as a report to The Nature Conservancy and complies management recommendations based on results from pilot studies.

CHAPTER 1:

DIFFERENCES IN SPACE USE AND DEN VISITATION BETWEEN TWO ENDEMIC CALIFORNIA CHANNEL ISLAND MESOCARNIVORES, THE ISLAND SPOTTED SKUNK (*SPILOGALE GRACILIS AMPHIALA*) AND ISLAND FOX (*UROCYON LITTORALIS*)

INTRODUCTION

Interspecific competition is an important mechanism structuring animal communities (Schoener 1974, Case and Gilpin 1974). Among carnivores, dominant competitors may restrict population size and distribution of subordinate species by both exploitative competition such as competing for the same resources and through interference competition in the form of mortality due to aggression and predation (Palomares and Caraco 1999). At the scale of individual home ranges, subordinate carnivores may be forced into areas not occupied by dominant carnivores in order to limit agonistic interactions. Among sympatric canids for example, smaller-bodied species tend to have smaller home ranges that are often on the edges or between the home ranges of larger species (Sargeant et al. 1987, Harrison et al. 1989, Thurber and Peterson 1992). In other cases, however, subordinate species may have larger home ranges and lower population densities than the dominant species, presumably because the smaller subordinate species is forced to move more widely to avoid the larger competitor (St-Pierre et al. 2006, Kamler et al. 2012). Intraguild predation among carnivores is an extreme form of competition and occurs most often when the dominant species is larger than the subordinate species (MacDonald and Sillero-Zubiri 2004, Thompson and Gese 2007). This additional mortality could increase the probability of extinction especially when the subordinate species become rare (Linnell and Strand 2000). Thus, understanding resource selection and niche differentiation among carnivores may be critical for conservation of subordinate carnivore species.

Niche differentiation and intraguild competition may be especially important on small, isolated islands with limited resources and relatively simple communities compared to the mainland (Paulay 1994). The California Channel Islands are home to only two mesocarnivore species, the island fox (*Urocyon littoralis*) and the island spotted skunk (*Spilogale gracilis amphiala*), with the fox characterized as the dominant competitor (Crooks and Van Vuren 1995, Jones et al 2008). While distinct subspecies of the fox exists on six of the eight Channel Islands, the spotted skunk is only present on two, Santa Rosa and Santa Cruz Islands. Historically, foxes and spotted skunks have coexisted on the islands of Santa Cruz and Santa Rosa since each species independently colonized the islands, with estimates for arrival for both species falling between 7,100 -11,500 years ago (Floyd et al. 2011, Hofman et al. 2015). During the mid- to late 1990's, golden eagles (*Aquila chrysaetos*) colonized the northern Channel Islands, in part due to the diminished population of a dominant competitor, the bald eagle (*Haliaeetus leucocephalus*), and presence of non-native ungulate prey (Coonan et al. 2010). Golden eagles also preyed heavily on foxes, reducing fox numbers to the point that they were eventually federally listed as endangered. During this period of declining fox numbers, the rate of spotted skunk captures on trapping lines increased exponentially, suggesting a release from competition with foxes (Crooks and Van Vuren 2000; Roemer et al. 2002; Jones et al. 2008). As fox populations have increased in the last decade, a corresponding decrease in capture rates of spotted skunks has led to concern over the long-term viability of the spotted skunk population (Dillon et al. in prep).

Previous studies have suggested niche differentiation between the island fox and spotted skunk based on differences in diet, temporal activity patterns and habitat preferences. Foxes have been characterized as the dominant competitor with a broad ecological niche based on their extensive use of various habitats on the island, omnivorous diet, and cathemeral activity patterns (Crooks and Van Vuren 1995). In contrast, spotted skunks display a narrower range of habitat use, have a mostly carnivorous diet and are primarily nocturnal (Crooks and Van Vuren 1995). Previous studies of spotted skunks on Santa Cruz Island were conducted during two time periods, the first in 1992 when spotted skunks were considered rare and foxes abundant (Crooks and Van Vuren 1995), and the second in 2003 when spotted skunks were considered abundant and foxes rare (Jones et al. 2008). In the first study, when both spotted skunks and foxes were studied simultaneously in two locations, at one study site spotted skunks selected scrub oak and ravine habitats more than expected and under-utilized fennel grassland habitat, while foxes showed the opposite pattern. However, at the other study site, spotted skunks selected grasslands and foxes showed no preferential selection, at least in the wet season (Crooks and Van Vuren 1995). In the second study, spotted skunks selected certain habitats more than expected but again patterns of selection were not consistent across sites or seasons (Jones et al. 2008). These variable results leave open the question of the extent to which habitat selection may reduce competition between the species.

A shift of spotted skunk den sites to more open, unprotected locations in the period when foxes were rare was hypothesized to be due to a release from predation by foxes on spotted skunks at den sites, suggesting intraguild predation may be important in these species' interactions (Jones et al. 2008). Individual spotted skunks will use multiple dens (Crooks 1994, Doty and Dowler 2006) and different individuals may use the same den (Lesmeister et al. 2009). Den locations can be highly variable, though studies of den sites of mainland spotted skunks suggested overall that dens were associated with higher vegetation cover (Doty and Dowler

2006, Lesmeister et al. 2009) and steeper slopes (Lesmeister et al. 2009). On Santa Cruz Island, spotted skunks were documented denning under shrubs, in open grassland, rock cavities, root cavities, tree trunks and under human structures (Crooks 1994). How differences in spotted skunk den sites might affect the probability that a spotted skunk den is visited by a fox has not been investigated.

The island spotted skunk currently has maintained populations on two Channel Islands for thousands of years in spite of competition from foxes, suggesting spotted skunks may have a realized niche that has allowed them to persist sympatrically with a dominant competitor like the fox. The main objectives of this study were to explore patterns of space use by spotted skunks and foxes using GPS telemetry and to use remote cameras to quantify the potential for interaction between the two species at spotted skunk den sites. We tested two *a priori* predictions. 1) Based on previous studies that found spotted skunks associated with canyons and ravines (Crooks and Van Vuren 1994, 1995) and areas of higher vegetative cover (Crooks and Van Vuren 1994, 1995, Neiswenter et al. 2010, Lesmeister et al. 2009), we predicted that spotted skunks would utilize areas of the island with either denser vegetation or steeper slopes than foxes. 2) Given the hypothesis that shifts from protected to unprotected den sites by spotted skunks was in response to a release from predation pressure during periods of low fox numbers, we predicted that fox visitation rate at spotted skunk dens would be greater at dens associated with lower vegetation cover. More generally, understanding habitat selection patterns of these two competing insular endemic species will expand our knowledge of community ecology and the mechanisms allowing coexistence among sympatric competitors.

METHODS

STUDY AREA

Santa Cruz Island (34.0232° N, 119.7658° W) is the largest of the California Channel Islands, encompassing 249 km^2. It is located approximately 30 km off the coast of southern California. Approximately 76% of the island is owned and managed by The Nature Conservancy and the remaining 24% by U.S. National Park Service. The island is approximately 34 km long and ranges from 3-11 km wide with a system of interior valleys to the east and west enclosed by mountain ranges to the north and south (Schoenherr et al. 1999). Mt. Diablo is the highest peak at 740 m. Climate is classified as maritime Mediterranean with hot, dry summers and cool, wet winters. The island supports several types of vegetation not limited to chaparral, coastal sage scrub, grassland and pine and oak woodlands (Junak et al. 1995). Other land mammals include the deer mouse (*Peromyscus maniculatus*), western harvest mouse (*Reithrodontomys megalotis*) and at least 11 species of bats (Laughrin 1982, Brown & Rainey 2018).

TRAPPING

Trapping was conducted over three timeframes: June-August 2018 and December-February 2019 to deploy all collars and June-August 2019 to recover collars. Spotted skunks and foxes were trapped using Tomahawk single-door box traps (Tomahawk Live Traps Co., Tomahawk, Wisconsin) and baited with wet/dry cat food and loganberry lure (U-Spray, Inc., Lilburn, GA). All trapped individuals were weighed, sexed, tagged with a passive integrated transponder, approximately aged and categorized as a young of the year, subadult, adult and senior by tooth wear. Foxes were given a body condition score from one to five, with one being thin and five being obese. Spotted skunks were classified as thin, moderate or fat body condition.

Spotted skunks receiving collars were immobilized using ketamine (20-25 mg/kg)-xylazine (2mg/kg) mixture. Once collaring was complete, spotted skunks were returned to the trap to recover and released a few hours later. Due to their docile nature, foxes were handled without anesthesia and after collaring was completed, they were immediately released. All animal procedures were done in accordance with Northern Arizona University IACUC Protocol 18-007.

GPS TELEMETRY

Between June-August 2018 and December 2018-February 2019, ten adult spotted skunks >500g were fitted with Lotek LiteTrack20-RF Swift Fix GPS collars (Lotek Engineering Inc., Newmarket, Ont., Canada). During August 2018, eight adult foxes >1.5 kg that were trapped in the vicinity of GPS collared spotted skunk capture sites were fitted with Lotek LiteTrack60-RF Swift Fix GPS collars (Lotek Engineering Inc., Newmarket, Ont., Canada). Fox and spotted skunk GPS collars were programmed to collect data differently for the two species, given differences in activity patterns and life of the collar battery. First, to determine space use over a longer time period, hereafter referred to as "rolling fixes", collars were programmed to take one fix every three days at 2200 hrs (spotted skunks) or one fix at 0100, 0300, 0600, 1200, 1800 and 2200 hrs every three days (foxes) for the life of the collar. Second, to determine space use in greater detail at specific periods of the year, hereafter referred to as "week fixes", collars were programmed to take one fix every 30 minutes between 1900-0700 hrs for one week during the fall (October), winter (February), spring (May) and summer (July) (spotted skunks), or one fix every 30 minutes between 0000-2359 hrs for one week every month (foxes).

After collection of data and before initial analyses, all coordinates were projected from geographic latitude and longitude to Universal Transverse Mercator (UTM) coordinates. GPS data were screened based on horizontal dilution of precision (HDOP). According to the manufacturer HDOP values <2 were considered ideal and values >10 should be treated with caution. However, previous GPS collar analyses have shown that intensive screening of GPS points did not prove to be beneficial and also tended to bias datasets to lower canopy cover and open terrain (Ironside et al. 2017), thus a liberal HDOP (<10) was chosen as a cutoff for our analysis. Points outside the boundary of the island were also removed. Data points were attributed with distance between consecutive points, distance from nearest road, degree slope, percent vegetation cover, and vegetation type (LANDFIRE 2014, U.S Geological Survey 2017, The Nature Conservancy 2019).

VHF TELEMETRY

To locate spotted skunk den sites, between January and February 2019, nine adult spotted skunks >500g were fitted with Holohil RI-2D VHF collars (Holohil Systems Ltd, Carp, Ont., Canada). Individual spotted skunks in their dens were located from the ground one to two times per week during daylight hours between January and May 2019, weather and road access permitting. Once a spotted skunk was located, UTM coordinates were taken using a handheld GPS unit (Garmin, Olathe, Kansas) along with a written detailed physical description of the den and a photo taken of the den entrance.

HOME RANGE ANALYSIS

Minimum convex polygon (MCP) and kernel density estimates (KDE) were used for home range analysis. MCP was calculated using the minimum bounding tool in ArcMap (10.4) and 100% isopleths were used to estimate MCP for each timeframe (rolling and week). ArcMET

(Wall, 2014), an add-on tool for ArcMap, was used to analyze KDE. The 95% isopleth (contour lines) were estimated using an optimum smoothing parameter (h-ref) chosen by the ArcMET program. All values are reported as hectares ± standard error. All GPS points (rolling and week) were used to calculate MCP, wheras only rolling fixes were used to calculate KDE.

To determine whether space use changed through time, percentage of intraspecific spatial overlap of week and rolling fixes was estimated by first calculating the MCP for each time frame then using the intersect tool in ArcMap. Percent overlap was calculated by dividing the area of overlap by the area of the rolling fixes. In order to calculate overlap between fall and winter week fixes, area of intersect was divided by combined area of fall and winter. Time frames compared were that of 1) October 2018 intensive week to August-October 2018 rolling, 2) January or February 2019 week to December 2018-February 2019 rolling, 3) October 2018 week to August 2018-February 2019 rolling, 4) January or February 2019 week to August 2018-February 2019 rolling, 5) October 2018 week to February 2019 week.

HABITAT ANALYSIS

To determine use and availability of habitat components for each animal and to determine if habitat selection changed through time, a three-month and six-month MCP (if applicable) was calculated for each animal. Using the random point generator in ArcMap, two sets of random points for fall and winter (if applicable) were generated within the MCP boundary. The number of random points were unique and determined by the amount of GPS points collected during each season (fall and/or winter) for each individual. Slope, vegetation type, and percent vegetation cover associated with each random point was calculated using the same method for GPS locations. Vegetation categories were removed from analysis if there were fewer than five

GPS and random points within them. To determine vegetation cover, raster percent vegetation cover data from the most recent available layer was downloaded from Landfire (LANDFIRE 2014) at a 30 m resolution. The rasters were then clipped to the island layer to exclude ocean values. A similar process was followed to associate each point with slope using data from U.S. Geological Survey-The National Map (USGS, 2017) at a 1/9 arc second for a finer grain resolution and vegetation type using a TNC provided polyline dataset (The Nature Conservancy, 2019). Distance from all roads (unpaved) was calculated for each point using the Euclidean distance tool in ArcMap (10.4) using a road layer provided by TNC (The Nature Conservancy, 2019). A 30 m resolution was found to be too coarse to capture the openness of roads therefore if a point located on the road, a default of 5 was used for percent vegetation cover regardless of the vegetation value for that pixel. The proportion of GPS points were compared to the proportion of random points using a chi-squared goodness of fit test to determine if habitat was being used relative to availability for each species (Manley 1993). To determine if habitat selection differed among different seasons, a chi-squared contingency test was used. Tests were considered significant if $P < 0.05$. Confidence intervals (95%) for each vegetation category were calculated following procedures in Lin et al. (2013) and positive or negative selection for a vegetation category was assigned if proportion of random points fell below or above the confidence interval for the observed values. Because the amount of slope and vegetation varies across the island, differences in habitat use, slope and vegetation cover, were tested using two sample t-tests only between a spotted skunk and fox living in the same area.

DEN SITE CHARACTERISTICS AND VISITATION

To assess characteristics that were associated with spotted skunk dens and how often dens were visited by foxes, Reconyx PC800 or MR5 remote cameras (Reconyx Inc., Holmen, Wisconsin) were placed at spotted skunk dens located during VHF tracking of spotted skunks. For the purpose of this study, dens were considered a site where a spotted skunk was found resting during the day. Den locations were recorded using UTM coordinates and cameras were mounted 2-5 m from the den opening. Camera motion triggers were set at medium-high sensitivity and programmed to shoot a burst of three photos when triggered, with a one second delay between photos. Fox and spotted skunk detection rates were calculated by dividing the number of species occurrences at the den site by the number of days the camera was operational. A detection was defined as each time a fox or spotted skunk entered the camera frame. Consecutive photos of the same species within a 30-minute time frame were considered to be the same individual and therefore counted as a single detection unless the animal in the sequence could be distinguished by an obvious characteristic such as presence of a VHF collar. If a spotted skunk used a den over consecutive days, each time it entered the den to rest for the day was counted as one detection. For each den site, slope, vegetation cover and vegetation type were calculated in ArcMap using the same methods described for habitat analysis. Linear regression was used to test for relationships between 1) fox detections and vegetation cover, 2) spotted skunk detections and vegetation cover, 3) fox detections and slope, 4) spotted skunk detections and slope and 5) spotted skunk detections and fox detections. Tests were considered significant if $P < 0.05$.

To compare prevalence of den types to previous studies, spotted skunk dens were categorized using a modified version of Jones et al. (2008) structure classification, which separated dens into five categories: 1) Dense woody vegetation: dens under woody plants which provided dense cover at ground level, 2) Open woody vegetation: dens under/inside woody plants that did not provided significant cover at ground level, 3) Herbaceous: dens in open areas covered by herbaceous plants not associated with woody vegetation, 4) Human made: non-rock dens under human made structures including log piles and 5) Rock: dens among rock. Dens were also classified based on exposure type as either: 1) Protected: den underground or within a tree trunk, or 2) Exposed: den above ground not within a trunk.

RESULTS

GPS TELEMETRY

We deployed 18 GPS collars on adult animals (eight foxes, ten spotted skunks) in various locations around the island (Figure 1.1). The mean body condition score for a collared fox was 2.75 (range = 2-3) and for a skunk, moderate, indicating healthy individuals. Partial datasets from 14 individuals (eight foxes, six spotted skunks) were acquired either through remote download or physical capture. By the end of field study (summer 2019) personnel were able to physically recover six of the eight fox collars and three of the ten spotted skunk collars. Extensive damage was observed on the recovered collars. All collars were missing antennas and were no longer transmitting RF/VHF signals. All fox collars were covered with bite marks and three were missing the GPS unit entirely. The carcasses of two collared animals (1 fox, 1 spotted skunk) were recovered but the cause of death could not be determined.

Overall, the average GPS fix success rate was 87 ± 4% for fox collars and 64 ± 9% for spotted skunk collars. Total successful fixes for all fox collars (M=5, F=3) was 13,829 out of 16,533 fix attempts. Fox fixes were reduced to 12,157 after screening for position accuracy, averaging 1,519 ± 383 valid fixes per collar. Total successful fixes for all spotted skunk collars (M=5, F=1) was 757 out of 1,243 fix attempts. Spotted skunk fixes were reduced to 666 after screening for position accuracy, averaging of 111 ± 38 fixes per collar. Number of GPS points varied across individuals and species due to collar damage and malfunctions. Of the six spotted skunks, two spotted skunks had only 5 GPS fixes, two had data for only fall (133 and 177 fixes), one had data from only winter (103 fixes) and one had data from both fall (144 fixes) and winter (84 fixes). Of the eight foxes, five had data for only fall (449, 454, 455, 469, and 475 fixes) and 3 had data for both the fall (445, 455, and 477 fixes) and winter (604, 616, and 645 fixes). Only one spotted skunk and three foxes collected concurrent week and rolling GPS data for both fall (August-October 2018) and winter (December 2018-February 2019) periods.

HOME RANGE SIZE THROUGH TIME

Overall, comparisons between home range size based on one week fixes, three months of rolling fixes and six months of rolling fixes revealed home range estimates for spotted skunks increased 8-fold over sampling duration, from a KDE mean of 36 ± 7 ha (MCP=33 ± 8 ha) for week fixes of three male spotted skunks to 299 ha (MCP=169 ha) for one male spotted skunk with a collar that functioned for six months. In contrast, home range estimates of foxes remained similar regardless of whether they were based on the intense week fixes, 78 ± 24 ha (MCP 66 ± 20 ha) for eight foxes (M=5, F=3), or the six months of rolling fixes, 83 ± 23 ha (MCP=100 ± 22 ha) for three foxes (M=2, F=1) (Figure 1.2). For foxes, MCP home range estimates based on fall one-week fixes overlapped that based on three months of fall fixes by 77% and that based on six months of fixes by 64%, indicating that foxes moved through slightly more than half of their six-month MCP in a week. The MCP home range estimates based on one week of fall fixes for the spotted skunk overlapped that based on three months of fall fixes by 32% and based on six months by only 8%, reflecting the tendency to use only a portion of a larger home range during a week (Figure 1.2 and 1.3). The mean overlap between MCP October week and January week for three foxes (M=2, F=1) was 60 ± 13 %. No overlap between the October week and January week for the spotted skunk was observed.

HABITAT SELECTION

The mean degree slope for all GPS points for eight foxes (M=5, F=3) was 20 ± 0.3 and four spotted skunks (M=3, F=1) was 22 ± 0.8. Mean percent vegetation cover for foxes was 34 ± 0.5 and spotted skunks was 39 ± 1.2. These comparisons were made by combining data across animals living in very different parts of the island which differed in the availability of both dense cover and steep slope. Although when averaged across all animals mean slope and vegetation cover did not differ between GPS locations of foxes and spotted skunks, within two pairs inhabiting similar parts of the island, at least one of those parameters did differ (Figure 1.4). When a fox and spotted skunk with overlapping home ranges in the Del Norte area of the island were compared, there were insignificant differences for slope ($t=-0.681$, $df=387$, $p=0.497$) but spotted skunk GPS locations were significantly higher in vegetation cover ($t=-9.2985$, $df=344.99$, $p=<0.05$). In contrast, for a spotted skunk and fox with overlapping home ranges in the Central Valley of the island, spotted skunk GPS locations were significantly higher in slope ($t=-3.633$, $df=280.47$, $p=<0.05$) and there was a non-significant trend for increased vegetation cover ($t=1.7406$, $df=306.38$, $p=0.083$).

Overall, foxes used more vegetation types than spotted skunks in both fall and winter (mean = 7 ± 0.7 and 7 ± 1.5 vegetation types in the fall and winter, respectively) than did spotted skunks (mean = 5 ± 0.3 and 4 vegetation types in the fall and winter, respectively) (Figure 1.5). Although all individuals showed selection for some vegetation types relative to availability, there was no consistent pattern of which vegetation types were over-selected by all individuals within species, either in the fall or winter (Table 1.1). Some patterns were suggestive, however. In the fall, two of the three spotted skunks under-utilized island buckwheat scrub and four of the eight foxes under-utilized California sagebrush scrub and island buckwheat scrub. In the winter, both spotted skunks under-utilized island buckwheat scrub and two of the three foxes under-utilized coastal and island scrub oak chaparral. Type of vegetation used differed significantly between fall and winter for both species (Table 1.2) but was more prominent for the spotted skunk (M=1) than three foxes (M=2, F=1) with home ranges in the same area of the central valley (Figure 1.5). During the fall, over 60% of GPS locations for the spotted skunk occurred in coastal and island scrub oak while only 16% of locations occurred in fennel. However, in winter over 60% of locations occurred in fennel while only 8% of locations occurred in coastal and island scrub. Foxes used a mixture of various vegetation types in both time periods.

SPOTTED SKUNK DEN MONITORING

Eighty-seven dens from nine VHF collared spotted skunks (M=8, F=1) were located and described. The majority of dens were associated with woody vegetation (82%, n=71), with far fewer associated with herbaceous cover (9%, n=8), human-made (5%, n=5) or rock crevices (4%, n=4) (Figure 1.6). All human-associated dens were in harvested eucalyptus logs that were stacked in large piles. Of the dens identified, 90% of the dens were classified as protected and 10% as unprotected. On only one occasion was a den site recorded as being reused by a different individual than the one initially found there.

During 2018-2019, 15 spotted skunk dens across the island were monitored by remote cameras. The average number of days a single den was monitored was 133 ± 24 days (min = 6, max = 361). One den was excavated to recover a dropped GPS collar, but due to continued occurrences of spotted skunks at the site, the camera was left in place and monitoring was continued. Spotted skunks were detected at 13 of the 15 dens an average of 7 (± 2.7 SE) times, ranging from 0-36 detections per month. At seven of the sites at least two different individuals visited the den on separate occasions as both collared and uncollared spotted skunks were photographed. At one den, at least three different spotted skunks visited, as there were photos of uncollared, VHF collared and GPS collared spotted skunks. Of the 15 dens monitored, only one site did not record a fox on camera. Vegetation cover did not predict the number of fox detections (R^2=0.008, P=0.766) nor did slope (R^2=0.082, P=0.318) (Figure 1.7). Vegetation cover also did not predict the number of spotted skunk detections (R^2=0.172, P=0.140) but slope was positively correlated with spotted skunk detection rates (R^2=0.392, $P<0.05$). There was no significant relationship between spotted skunk and fox detections at den sites (R^2=0.167, P=0.146), although the den site with the highest fox visitation had low spotted skunk visitation. At one den site, a series of photos captured a fox digging at the den entrance while an adult spotted skunk was inside (Figure 1.8). In this series, a spotted skunk entered the den at 0157 hrs and later that day at 1303 hrs a fox arrived and dug at the entrance until 1309 hrs, when the fox left and did not return. That night at 1802 hrs the spotted skunk emerged and appeared unharmed.

DISCUSSION

HOME RANGE

For both the island fox and spotted skunk we found larger home range sizes than previously reported on Santa Cruz Island. In 1992, Crooks and Van Vuren (1996) found mean fox home range size varied between 25-32 ha (n=12) and in 1994, Roemer et al (2001) reported an overall mean size of 55 ha (n=14), both smaller than the mean three month range size of 74-75 ha in fall (n=8) and mean six-month home range size of 82 ha (n=3) found in this study. Home range estimates of island foxes on other islands, however, were similar to or larger including 75 ha on San Clemente (Resnik 2012), 105 ha on Santa Catalina (J. King, unpublished data), 181 ha on San Nicolas (Powers 2009) and 339 ha on Santa Rosa (Drake et al. 2015). Our seasonal estimates of home range in spotted skunks was also larger than previous reported, varying between 198-229 ha in the fall (n=3) and winter (n=2) with an overall six-month home range size of 299 ha (n=1). In comparison, Crooks and Van Vuren (1995) reported mean home range sizes of 23 ha (n=7) during the wet and 40 ha (n=1) during the dry seasons and Jones et al. (2008) reported a mean seasonal home range size of 39 (n=33) and annual home range size of 52 ha (n=6). Both Crooks and Van Vuren (1996) and Roemer et al. (2001) utilized VHF collars and monitored foxes over an entire year and included study sites on different parts of the island.

Home range estimates are sensitive to the number of locations collected for each animal. Some studies have estimated that a minimum of 30-100 locations are necessary to reach an asymptote for estimates of seasonal home ranges and 300 for annual home ranges (Seaman et al. 1999, Girard et al. 2002). Previous studies of fox home ranges were determined by obtaining 632 VHF telemetry locations ($\bar{x}$ =26 per fox) in Crooks and Van Vuren (1996) and ~5,700 VHF telemetry locations ($\bar{x}$=133 per fox, approx.) in Roemer et al. (2001) study, compared to the

~12,000 ($\bar{x}$ =1,520 per fox) GPS locations collected in our study. Likewise, for island spotted skunks, previous studies relied on VHF collars and much smaller numbers of locations, with Crooks and Van Vuren (1996) having a seasonal average of 27 VHF locations per spotted skunk and Jones et al. (2008) a seasonal average of 29 VHF locations per spotted skunk. In comparison, our study collected ~660 ($\bar{x}$=110 locations per spotted skunk) total GPS locations.

Biological factors could also contribute to differences in home range estimates. Home range may vary with age of the study animal, conspecific density and food availability (Benson et al. 2006, Schradin et al. 2010). Only adult animals were collared in this study. Foxes were abundant and spotted skunk uncommon during our study, similar to those in previous studies conducted in the early 1990's (Crooks and Van Vuren 1996), so differences in density are unlikely to explain the differences in home range we documented. Likewise, body condition of foxes and spotted skunks trapped during our study did not indicate the kind of nutritional stress that would likely be associated with a major shift in food availability. Body conditions between 2-3 for foxes and a moderate body classification for spotted skunks are typical for healthy wild individuals (C. Gagorik, personal comm.). The larger home range of spotted skunks relative to foxes is consistent with the hypothesis that large home ranges result from subordinate species moving more widely through the landscape to avoid the dominant competitor (St. Pierre et al. 2006, Kamler et al. 2012).

The temporal pattern of space use by foxes was strikingly different from that of spotted skunks in our study. Relative to foxes, spotted skunks used a larger home range over time but used only a fraction of that area over shorter temporal periods of weeks or months. A consistent pattern seen during the fall and winter periods was the tendency of island foxes to move through a large percentage of their tri-monthly home range in the course of a single week. These weekly movements overlapped their three-month seasonal home range by an average of 76% in the fall and 62% in the winter. In contrast, island spotted skunks showed more restricted movements across time, using a much smaller percentage of their tri-monthly home range during a similar one-week period. Weekly overlap between seasonal home ranges for a spotted skunk encompassed a mean of 32% in the fall and 34% in the winter, while no overlap of weekly home range occurred between fall and winter.

One caveat of this study is that it is based on primarily male spotted skunks and males tend to have larger home ranges (Jones et al. 2008), especially during the breeding season (Lesmeister et al. 2009). Western spotted skunks exhibit delayed implantation, with breeding occurring in the fall and parturition in the spring, and it is hypothesized island spotted skunks may follow the same pattern (Mead 1968). Thus, the fall home range estimates we obtained may be inflated if males were travelling to find females during this period. This does not explain the equally large home range for the male spotted skunk we tracked in the spring. Further exploration of spotted skunk breeding ecology will likely aid in understanding movement patterns.

HABITAT SELECTION

Overall our study was consistent with island foxes using a broader array of vegetation types than spotted skunks and selection for specific vegetation types in both species varying among individuals across locations. In previous studies, island foxes showed selection for fennel grasslands and avoidance of ravines and scrub oak patches at one site and no selection for habitat types in another (Crooks and Van Vuren 1995), while spotted skunks showed preferences for ravines, coastal sage scrub and avoidance of fennel and scrub oak at one site and preferences for grassland at another (Crooks and Van Vuren 1995). Jones et al. (2008) likewise reported spotted skunk selection for habitat types varied with both seasons and across sites. The spotted skunk in our study showed a strong preference for fennel in the winter, and a shift from selection for scrub oak in the fall to underutilization of that vegetation type in the winter. This variation in habitat selection across space and time may reflect the seasonality of resources, such as prey availability, that are unique to vegetation type or the diversity of vegetation communities and topography that characterize Santa Cruz Island. This finding contrasts with studies of mainland spotted skunks in less complex habitats like those in Arkansas where positive selection for shortleaf pine and hardwood stands was consistent across seasons (Lesmeister et al. 2009).

When we examined habitat by quantifying habitat based on vegetation cover and slope, overall, we found no differences between foxes and spotted skunks when animals across several different parts of the island were compared. However, in the two cases where a fox and spotted skunk were monitored simultaneously in the same location, spotted skunks used denser cover in one location and steeper slopes in the other. This suggests that differences in habitat selection based on slope and vegetation density may depend on the local availability of these environmental parameters. Foxes were also found to select for valley bottoms and avoid steep slopes in a study done on Santa Rosa Island (Drake et al. 201). Our comparison of the two pairs of spotted skunks and foxes that had overlapping home ranges in two different areas of the island highlight how these factors could interact with differences in terrain and vegetation community. In an area of relatively flat or rolling terrain, the spotted skunk selected areas with higher vegetation cover than the fox, while in an area of with greater topographic relief, the spotted skunk selected areas of steeper slope but not of higher vegetation cover. This suggests that spotted skunks and foxes may partition habitat differently in areas across the island depending upon availability along these two axes. We warrant caution in interpreting these results as there may have been uncollared foxes and spotted skunks in the study area who may have been using areas differently than what we illustrate here.

SPOTTED SKUNK DEN MONITORING

Crooks (1994) first reported that island spotted skunk dens were found in a variety of substrates but often under some form of cover. Later, during the period when the fox population was at its lowest, spotted skunks were documented using more unprotected den sites, suggesting a release from interference competition and that spotted skunks might avoid foxes by denning in more densely vegetated areas (Jones et al. 2008). Contrary to our predictions, we found neither vegetation cover nor slope predicted fox visits, nor were spotted skunk visits and fox visits at dens negatively correlated, which we would expect if dens were selected to minimize contact between species. Dens did vary in how often they were used by spotted skunks and we found a significant positive relationship between spotted skunk den visits and slope, suggesting spotted skunks may use dens on higher slopes more often, consistent with selection for slopes reported for some mainland spotted skunk populations (Lesmeister et al. 2009). We observed selection for woody-associated dens similar to that reported for spotted skunks when fox densities were low (Jones et al. 2008), but also a shift towards more protected dens similar to when fox populations were relatively high in 1992 (Crooks and Van Vuren 1994).

Although the potential for foxes to prey on spotted skunks in their dens has been hypothesized, and spotted skunks have been reported in the scat of island foxes (Cypher et al. 2014), we report the first camera evidence of a fox attempting to dig up a den while an adult spotted skunk was inside. Predation at den sites is not uncommon in systems where multiple carnivore species overlap in space and diet. In Africa, spotted hyenas have been reported to disturb African wild dog dens sites and kill young (Creel and Creel 1998) and in Scandinavia, red foxes have been observed killing an arctic fox adult and cub (Frafjord et al. 1989). Although our study focused primarily on male spotted skunks, females, especially those with kits, may be most vulnerable and therefore most sensitive to interactions with foxes. Den sites may provide opportunities for foxes to target young spotted skunks when mothers are away during foraging periods. We encourage further research that examines how important fox predation at den sites may be as a mortality factor in spotted skunks and how this interference could affect recruitment of young into the population.

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FIGURES

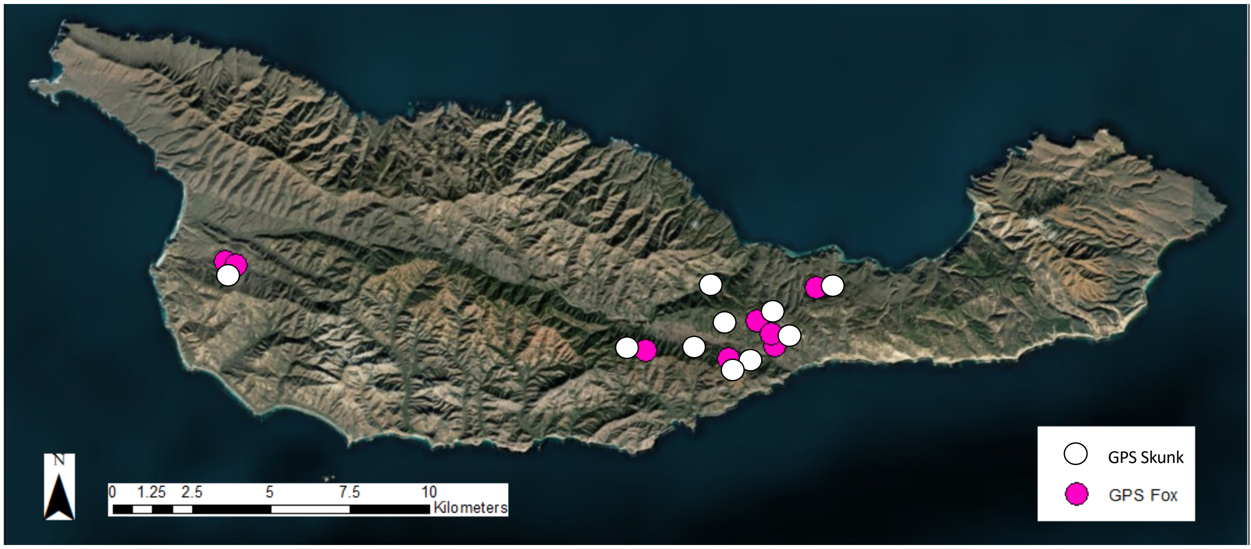

Figure 1.1: Locations where island spotted skunks and island foxes were trapped and GPS collared on Santa Cruz Island, CA.

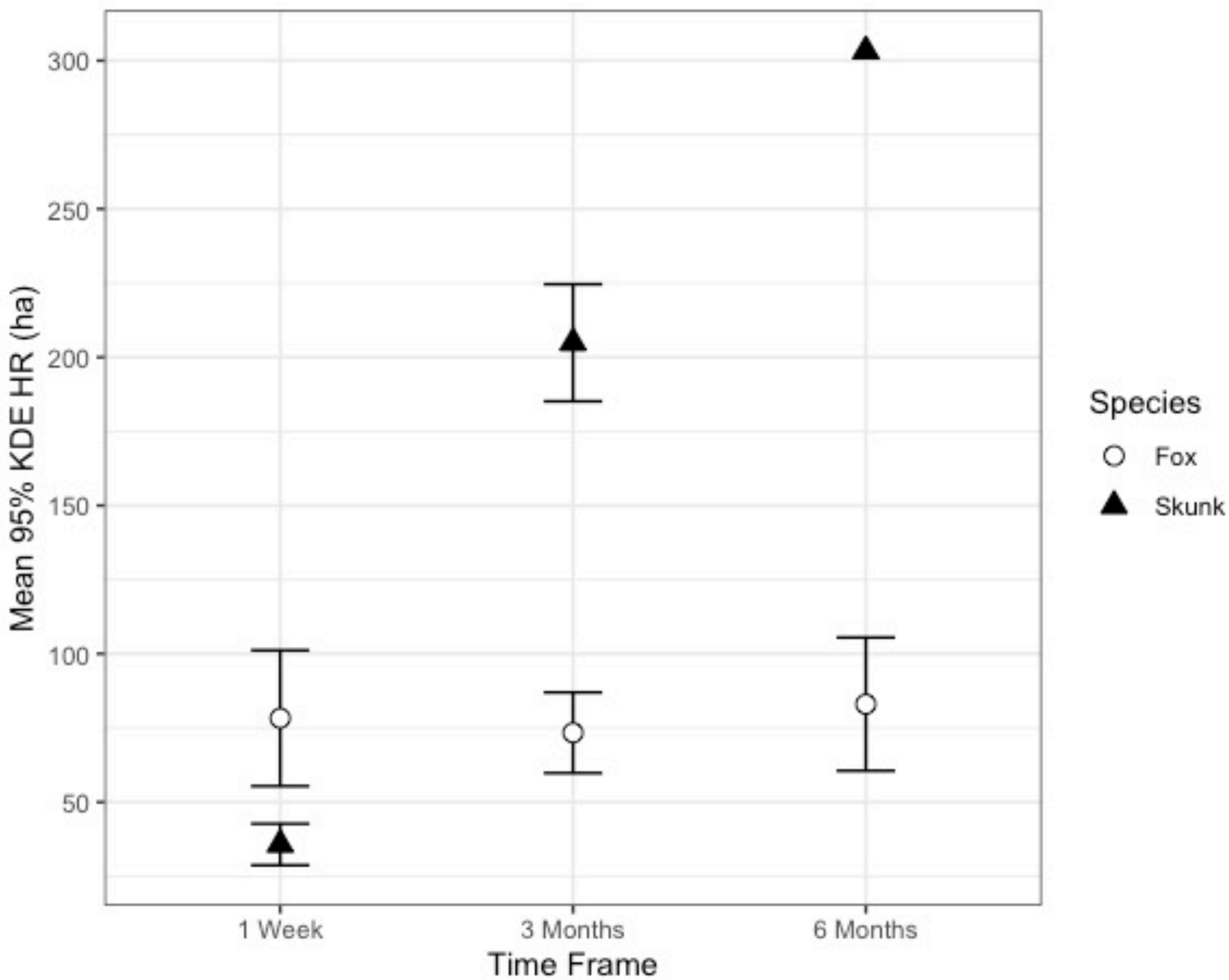

Figure 1.2: Mean (± SE) 95% kernel density estimate (KDE) home ranges for spotted skunks and foxes based on locations collected over one week, three-months and six-months with standard error bars. Data were only available for one spotted skunk during the six-month time frame. Minimum convex polygon and mean 50% KDE displayed similar patterns.

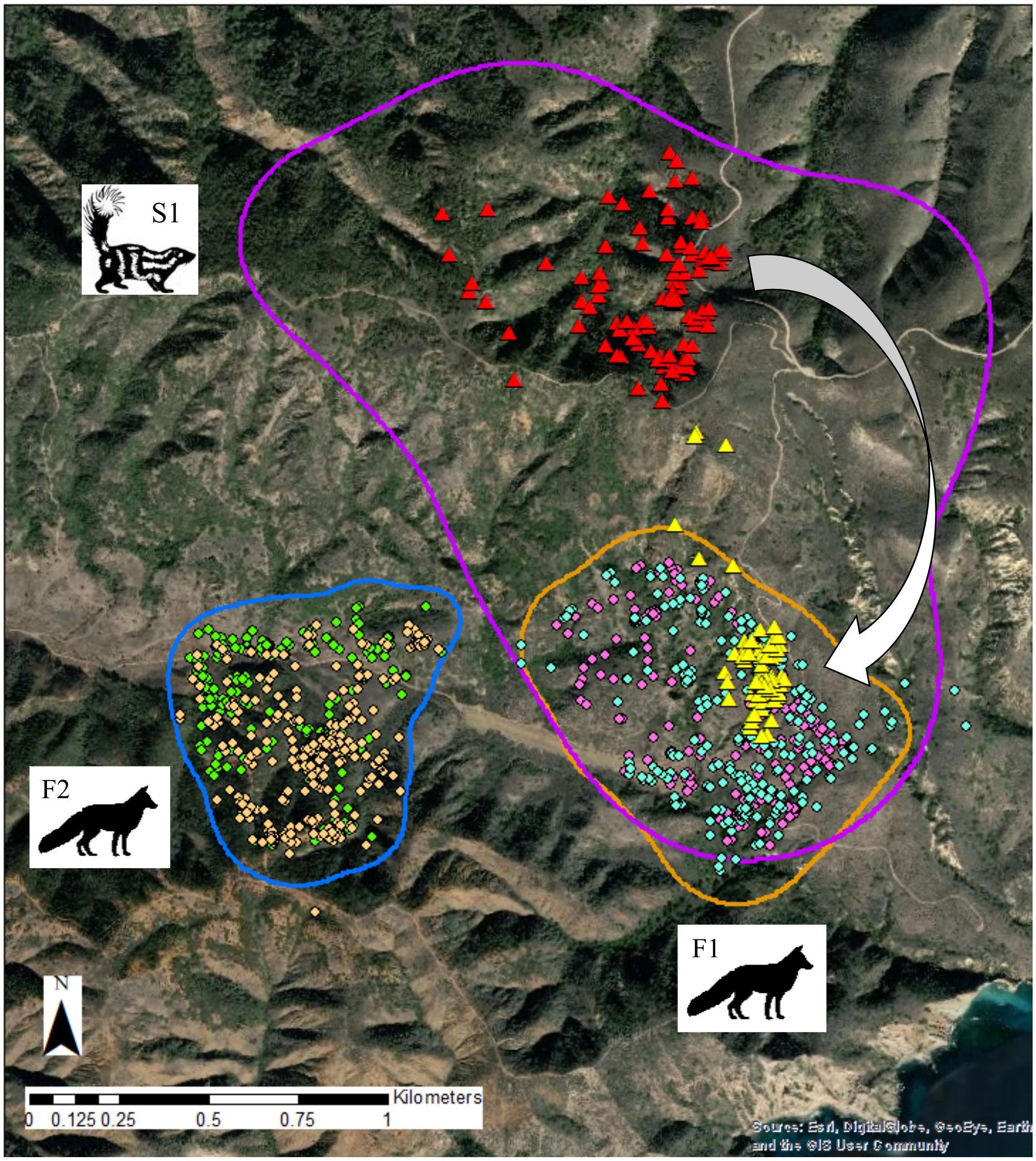

Figure 1.3: Fall and winter week GPS fixes and 95% KDE contour line based on 6-month (August –February) rolling fixes for two island foxes and one island spotted skunk living in the central valley of Santa Cruz Island, California. For the spotted skunk (S1), red triangles indicate GPS fixes for the fall week, yellow triangles the winter week fixes and purple line the 95% 6-month KDE. For the fox (F1), turquoise circles represent fall week fixes and pink circles represent winter week fixes with orange line the 95% 6-month KDE. For the second fox (F2), tan circles represent fall week fixes and green circles represent winter week fixes and blue line the 95% 6-month KDE. The white arrow highlights the shift of locations from fall to winter for the spotted skunk.

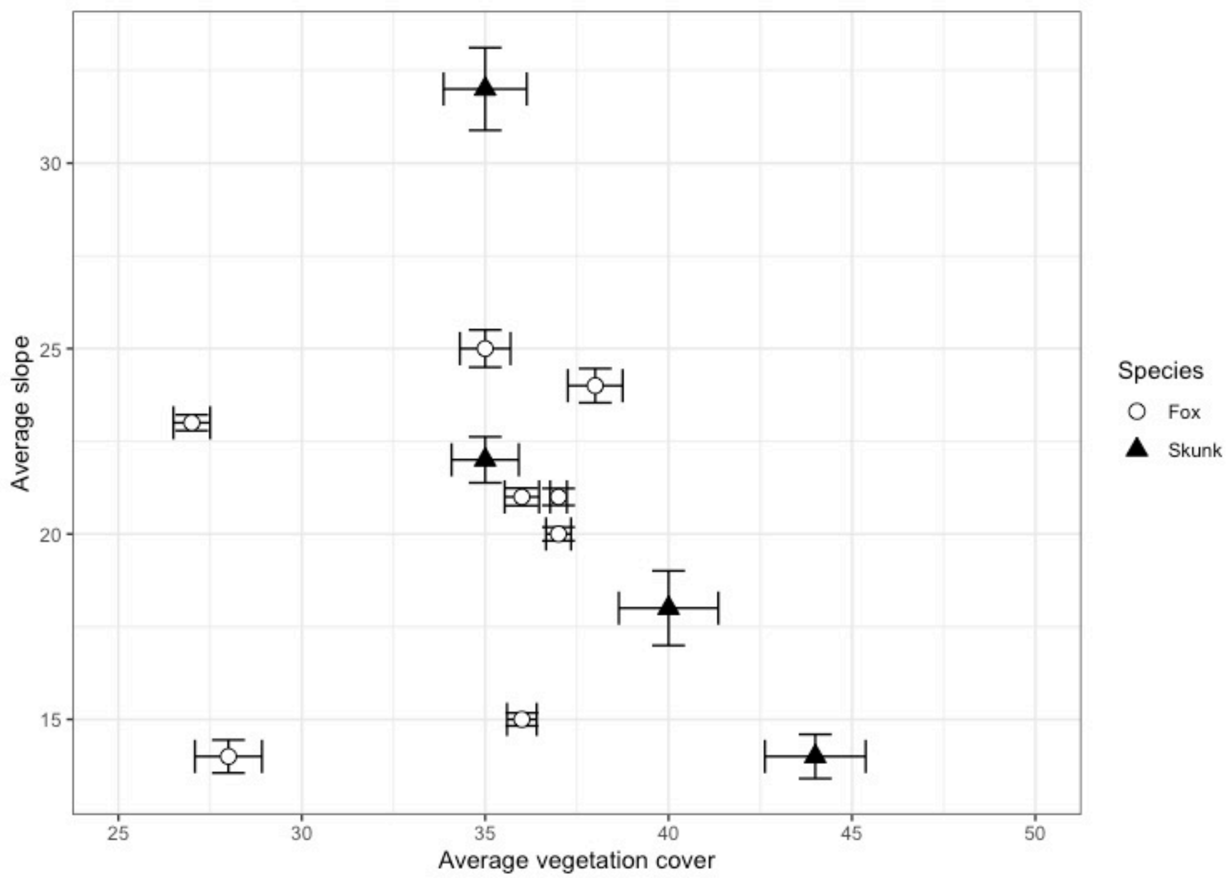

Figure 1.4: The mean degree slope (±SE) and percentage vegetation cover (±SE) calculated for eight island foxes and four spotted skunks based on all data points collected from GPS collars.

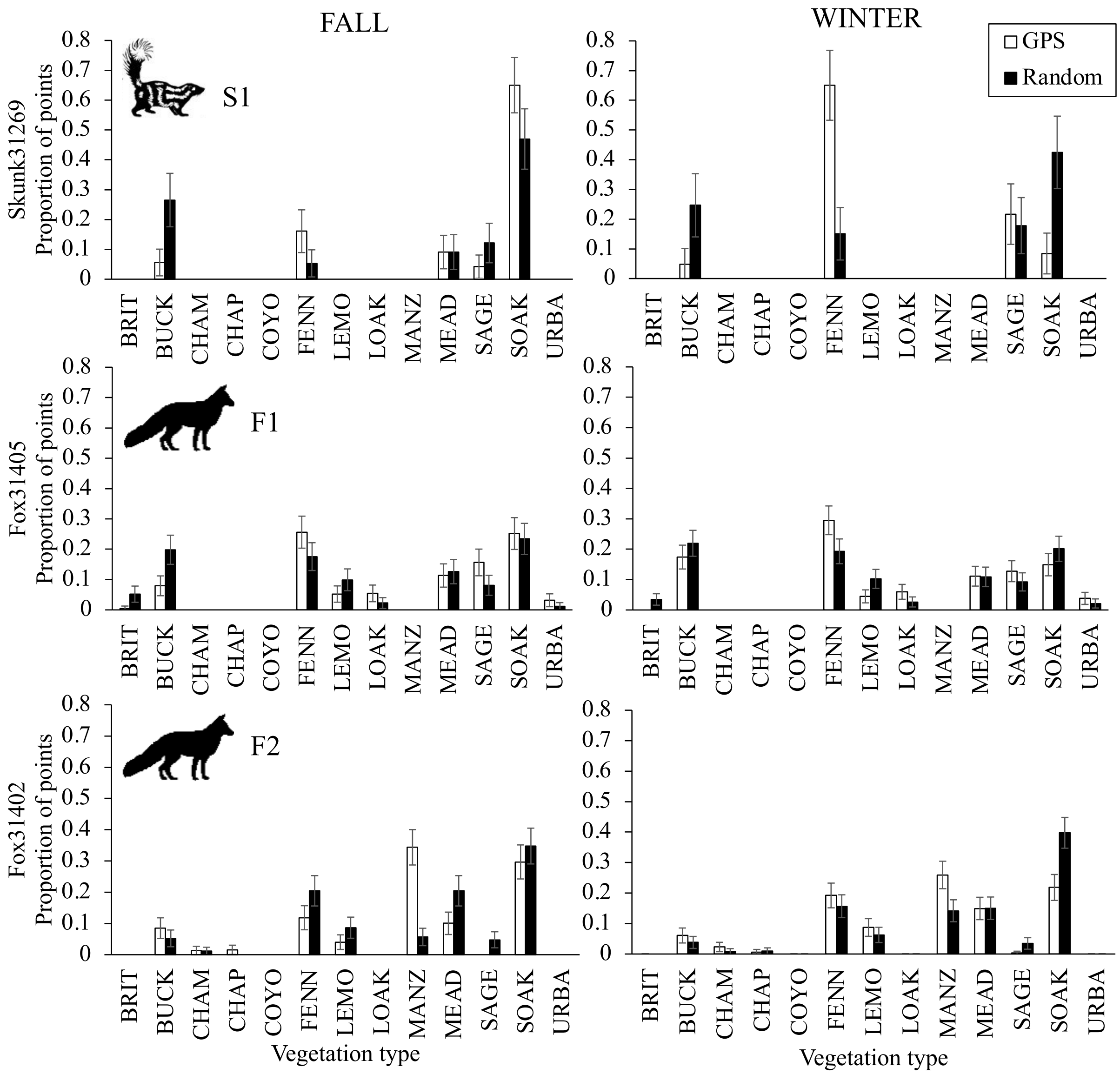

Figure 1.5: Proportion (±SE) of GPS and randomly generated points within the individuals home range during the fall and winter that were associated with vegetation type for the spotted skunk and two foxes living in the same area of the island. Illustrated is the major shift from scrub oak in the fall to fennel vegetation type in the winter for the spotted skunk contrasting with the similarity in vegetation type use between seasons for the foxes. Refer to Table 3 for vegetation type code definitions.

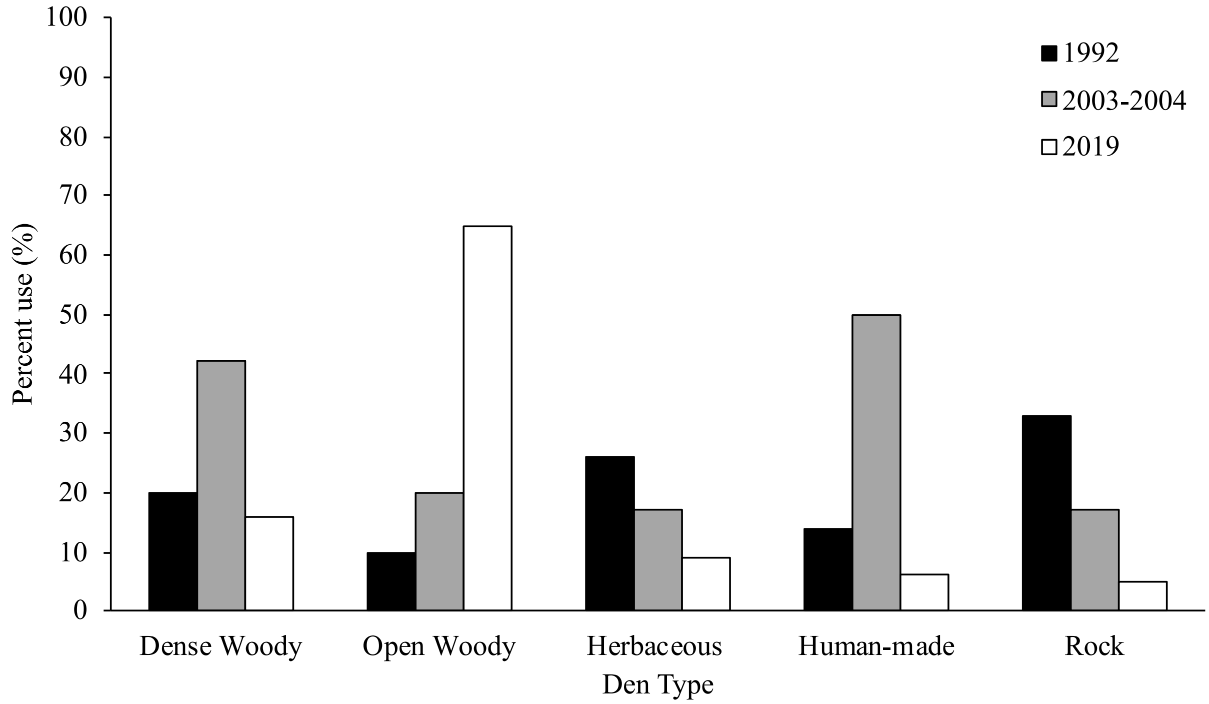

Figure 1.6: Spotted skunk dens associated by structure over three different study periods (Crooks 1994, Jones et al. 2008).

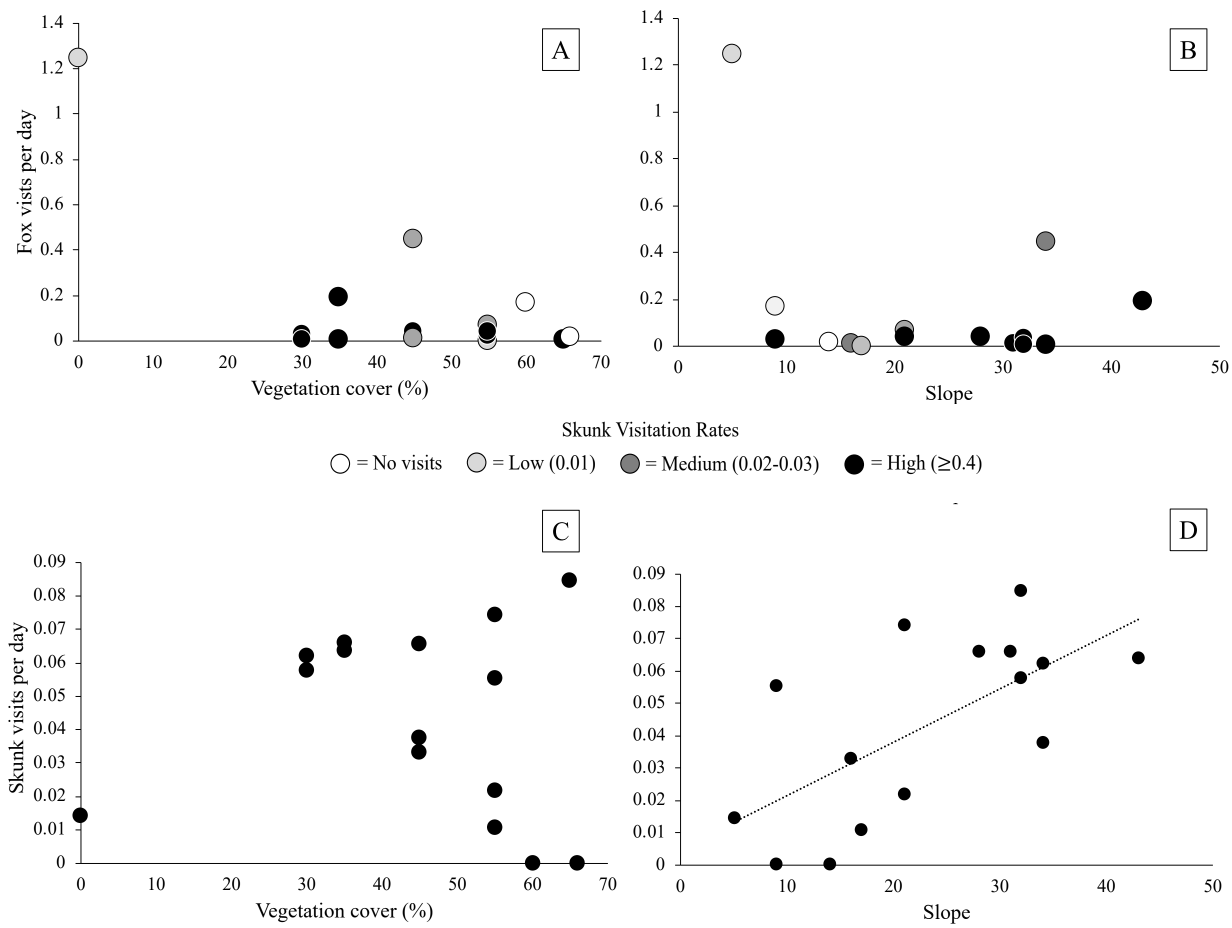

Figure 1.7: Island fox visitation rates per day at island spotted skunk dens on Santa Cruz Island, CA with varying (A) percentages of vegetation cover (R^2=0.008, df=1, P=0.766) and (B) slope (R^2=0.288, df=1, P=0.318). In each case spotted skunk visitation rates per day were defined by shading of the circle; no visits=no shading, low (0.01)=light grey, medium (0.02-0.03)=dark grey and high (≥0.4)=black. Relationships between spotted skunk visitation rates per day at the same dens sites with varying (C) vegetation cover (R^2=0.172, df=1, P=0.140) and (D) slope (R^2=0.391, df=1, P=0.017).

Figure 1.8: Series of photos captured by den camera (ID: Camera#10) of a fox digging at a den entrance during the day while a spotted skunk was inside

ID	Season	df	χ2	p
Fox31402	Fall	8	564.24	<0.001
	Winter	8	145.99	<0.001
Fox31405	Fall	8	144.95	<0.001
	Winter	8	152.80	<0.001
Fox31407	Fall	7	328.02	<0.001
	Winter	7	150.89	<0.001
Skunk31269	Fall	4	64.88	<0.001
	Winter	3	174.24	<0.001

Table 1.1: Vegetation associated with GPS versus randomly generated points during the fall and winter seasons for three island foxes and one spotted skunk analyzed using chi-square goodness of fit test.

ID	df	χ2	p
Fox31402	8	41.27	<0.001
Fox31405	8	34.58	<0.001
Fox31407	7	99.81	<0.001
Skunk31269	4	97.73	<0.001

Table 1.2: Vegetation associated with fall versus winter GPS points for three island foxes and one spotted skunk analyzed using the chi-square contingency test.

Code	Vegetation type/habitat
BRIT	California Brittlebrush & Ashy Buckwheat Scrub
BUCK	Island Buckwheat Scrub
CHAM	California Chamise Scrubland
CHAP	Blue Blossom Chaparral
COYO	Coyotebrush Scrub
FENN	Fennel
LEMO	Lemonade Sumac Coastal Bluff Scrub
LOAK	Coast Live Oak Woodland
MANZ	Central California Coast and Island Manzanita Shrubland
MEAD	California Grassland & Meadow
SAGE	California Sagebrush Scrub
SOAK	Coastal and Island Scrub Oak Chaparral
URBA	Urban/Unpaved road

Table 1.3: Vegetation codes for Figure 6.

CHAPTER 2:

MANAGEMENT RECOMMENDATIONS FOR AN ENDEMIC CALIFORNIA CHANNEL ISLAND MESOCARNIVORE, THE ISLAND SPOTTED SKUNK (*SPILOGALE GRACILIS AMPHIALA*)

INTRODUCTION

Long-term monitoring is an essential tool that helps ecologists track population dynamics, identify critical habitat, assess extinction risks and make management decisions for wildlife (White 2019). Management strategies play an important role particularly for island endemic species, many of which are at risk for extinction due to their small population size, lack of genetic diversity, and reduced defense mechanisms (Vitousek 1988). The use of global positioning system (GPS) collars and remote camera traps are two monitoring tools that have become increasingly popular due to improved technology and multi-faceted applications which can be used to inventory species, explore movement patterns and improve habitat models (Hebblewhite and Haydon 2010, Tobler et al. 2008). Remote cameras in particular are a non-invasive method that can provide a cost-effective means for estimating densities of rare and hard to detect species. This method is particularly useful for carnivores, many of which are elusive and occur in low densities that make them difficult to detect by conventional trapping methods (Ferreras et al. 2018). The addition of visual or olfactory attractants in combination with remote cameras can be used to increase detection probability, optimize survey efforts (Schlexer 2008) and offer an alternative method for assessing populations.

On the California Channel Islands, annual population monitoring of the endemic island fox (*Urocyon littoralis*) has been required as part of its species recovery plan. Grid-based monitoring was implemented in 2008 to standardize fox population and density estimates by using mark-recapture methods. Locations of eighteen grids (reduced to 12 in 2015, Figure 2.1) were randomly generated and then permanently placed across the island with requirements that grids would be spaced >1,500m apart. To ensure the safety of field personnel, the grids were also required to originate on a road or trail and avoid slopes greater than approximately 17 degrees (Rubin et al. 2007). A single grid consisted of an array of 12 box traps spaced ~200m apart in a 2x6 ladder-like configuration and were open for 6 consecutive nights during the summer/fall each year. Though trapping methods and design were implemented with foxes in mind, the endemic island spotted skunk (*Spilogale gracilis amphiala*) was also captured on these trapping grids. In the last decade, monitoring has indicated that adult fox density on Santa Cruz Island has almost doubled from approximately 4 adult foxes/ km^2 in 2008 to 7.5 adult foxes/ km^2 in 2019 (Dillon et al. in prep). Concurrently, spotted skunk trapping success dropped from approximately 16% in 2008 to <1% in 2019 (Dillon et al. in prep) (Figure 2.2). Decreasing spotted skunk trap success on monitoring grids has been seen on both Santa Cruz and Santa Rosa islands and has led to concern over the long-term viability of the spotted skunk populations.

The main objective of this chapter is to assess current approaches, report results of pilot studies to enhance those approaches and offer management recommendations for future monitoring of spotted skunks on Santa Cruz Island in light of the recent decline. Specifically, the following questions were addressed. 1) Does current spotted skunk trapping success observed on the fox monitoring grids adequately reflect spotted skunk populations through space and time? 2) Can detection of spotted skunks be enhanced by altering trap and/or camera placement or through the use of scent attractants? 3) Are current spotted skunk monitoring trends representative of a decline beyond historical population levels?

QUESTION 1: DOES CURRENT SPOTTED SKUNK TRAPPING SUCCESS OBSERVED ON THE FOX MONITORING GRIDS ADEQUATELY REFLECT SPOTTED SKUNK POPULATIONS THROUGH SPACE AND TIME?

HABITAT ANALYSIS AND MONITORING GRIDS

Currently there is no standardized monitoring program for the spotted skunks and hypothesized abundance is largely based on incidental captures on fox monitoring grids. Population grid-based trapping was designed for the foxes in regard to bait used and time of year trapping occurs. Thus, grids may not be an adequate tool for detecting spotted skunks. In a previous study that placed remote cameras on monitoring grids, Bolas et al. (2020) found that temporal variation detections of skunks increased from summer to winter indicating monitoring may be more effective in the fall. Bolas et al. (2020) also found no differences between camera and live trap methods during the late summer. However, less than one spotted skunk per 100 detection nights were observed for both camera and live trap methods (Bolas et al. 2020, A. Dillon, unpublished data).

Using the GPS telemetry habitat analysis explained in detail in Chapter 1, percentage vegetation cover and degree slope were calculated and averaged for all GPS collared foxes and spotted skunks over the life of the collar. Slope and vegetation cover were also calculated in ArcMap (10.4) for all 12 traps on each fox monitoring grid run between 2015-2019 using raster data from Landfire (LANDFIRE, 2014) and U.S. Geological Survey-The National Map (USGS, 2017). The rasters were joined to the GPS point locations of the traps so that each point contained the associated data. These values were then averaged so each grid was associated with a single vegetation cover and slope value.

Spotted skunks captured on monitoring grids between 2015-2019 were associated with trap and grid location using information from the long-term monitoring database. Based on the number of individual spotted skunk captures between 2015-2019, grids were classified as one of three categories. 0-no spotted skunk captures, 1-one spotted skunk capture and 1+ more than one spotted skunk capture. Multiple regression was used to test if average slope and average vegetation cover of a grid determined spotted skunk captures. Tests were considered significant if $P < 0.05$. Minimum convex polygon (MCP) home range estimates for GPS and VHF collared animals were calculated using the minimum bounding tool in ArcMap (10.4) using 100% isopleths.

The mean slope of a fox monitoring grid was 16 ± 2 SE (max 29, min 5) and percent vegetation cover 36 ± 6 SE (max 63, min 12). When the mean slope and vegetation cover values associated with a fox grid were compared to GPS data from individual foxes and spotted skunks, mean slope of a grid fell below the values from 5 of the 6 GPS spotted skunks and the vegetation cover fell below values for 4 of the 6 GPS spotted skunks (Figure 2.3). Over the course of 2015-2019, 32 newly tagged or previously passive integrated transponder (PIT) tagged spotted skunks were captured on the monitoring grids and the majority of these spotted skunk captures occurred on monitoring grids of relatively steeper slope and higher vegetation cover (Figure 2.4). However, multiple regression indicated that mean vegetation cover and slope of a monitoring grid did not predict the number of spotted skunks captured (R^2=0.277, P=0.233) (Figure 2.5).

The hypothesis that spotted skunks may be in the vicinity of fox grids but not detected on those grids is supported by a combination of data from intensive live-trapping, collaring and cameras placed on dens in the central valley between 2018-2019. Although at minimum 12 individual spotted skunks (identified by presence and type of a collar) were present in the area, the three fox monitoring grids in that area failed to capture any spotted skunks in 2019 (Figure 2.6). More broadly, only one spotted skunk was captured on all the fox grids monitored during 2019 while opportunistic trapping lines set either to vaccinate foxes or retrieve GPS collars captured seven individual spotted skunks. It is unlikely foxes filling traps before spotted skunks could be captured influenced spotted skunk capture success in 2019, as fox capture success on monitoring grids fell from 71% in 2018 to 51% in 2019. The tendency of spotted skunks to utilize only a portion of their home range during any one time of the year (Chapter 1) and long distance movement observed by some individuals (Figure 2.6) suggest that grids set for relatively short periods may fail to capture spotted skunks with home ranges that include those trapping grids. Grid traps are also only open for 6 nights and this is likely too short of a time frame to capture a spotted skunk that spends only a portion of its time in that part of its home range.

QUESTION 2: CAN DETECTION OF SPOTTED SKUNKS BE ENHANCED BY ALTERING TRAP AND/OR CAMERA PLACEMENT OR THROUGH THE USE OF SCENT ATTRACTANTS?

HABITAT MAP

In order to further explore areas of the island that might be more suitable for monitoring spotted skunks, raster layers of the island were created in ArcMap based on slope and percentage vegetation cover features and then assigned a simplified value for classification. Using habitat analysis results from the GPS collars, we classified slope and vegetation cover into high and low categories based on values derived from the mean slope and vegetation cover used by all animals under the hypothesis that in the presence of foxes, spotted skunks realized niche would lie above slopes of 25 degrees and vegetation cover above 40%, in areas not heavily utilized by foxes.

Using these parameters, areas of low slope (0-25 degrees) were assigned a value of 0 while areas of steep slope (>25 degrees) were valued at 1. A separate raster was created to evaluate areas based on vegetation cover by assigning a value of 0 to areas of low cover (0-40%) while areas of high vegetation cover (40%+) were valued at 10. These two rasters were then combined to identify areas on the island of low slope, low vegetation cover (value 0); low slope, high vegetation cover (value 1); high slope, low vegetation cover (value 10); and high slope, high vegetation cover (value 11).   We determined 20% (77,276 km^2) of the island was classified as category 1- low vegetation cover and low slope, 24% (92, 882 km^2) as category 2- low vegetation cover and high slope, 7% (27,265 km^2) as category 3-high vegetation cover and low slope and 48% (184,367 km^2) as category 4-high vegetation cover and high slope (Figure 2.7). Category 4 highlighted many drainages and included the majority of the northern shore of the island, where few surveys have been conducted in the past. These areas may represent habitats that have been under-monitored where spotted skunks might be more abundant. Although access to this area can be difficult, a modified trapping program or placement of cameras could yield valuable information about population trends for both foxes and spotted skunks in areas of the island where little data currently exists.

CAMERA STATIONS ON RIDGE TOPS VERSUS DRAINAGE BOTTOMS

To explore whether foxes and spotted skunks used ridge lines or drainage bottoms similarly, paired cameras (Reconyx PC800 or MR5 Reconyx Inc., Holmen, Wisconsin) were placed in four sites within the Central Valley. At each site, one camera was placed at the top of a ridge and the other in the adjacent drainage bottom habitat. Cameras were secured to posts or trees and placed in natural clearings. All cameras were placed in June 2019 and removed in

August 2019. Protocol for recording fox and spotted skunk detections at each site were the same as described in den monitoring.

Camera stations were active for a total of 61 days between June-August 2019. The average number of detections for foxes and spotted skunks at a drainage site was 7.5 ± 4.3 and 1.8 ± 1.4 respectively. The average number of detections for a fox at a ridge site was 8.5 ± 4.3. Spotted skunks were not recorded at any of the ridge camera sites. These preliminary results suggest deploying cameras along drainage bottoms may provide an effective way to detect spotted skunks and further examination of the roles drainage bottoms may play for spotted skunk movement should be continued.

SPOTTED SKUNK DEN MONITORING

To assess whether camera monitoring at spotted skunk den sites could be an effective way of monitoring spotted skunks over time, remote cameras (Reconyx PC800 or MR5 Reconyx Inc., Holmen, Wisconsin) were placed on 15 spotted skunk dens located during VHF tracking of spotted skunks. Dens were marked with UTM coordinates and cameras were mounted 2-5m from the den opening. Cameras were set at medium-high sensitivity and programmed to shoot a burst of three photos when triggered with a one second delay between triggers. Spotted skunk visits per day were calculated by dividing the number of occurrences at the den site by the number of days the camera was operational. An occurrence was defined as each time a spotted skunk entered the camera frame. Consecutive photos of the same species within a 30-minute time frame were considered to be the same individual and therefore a single occurrence unless they were distinguishable by an obvious characteristic such as a collar. If a spotted skunk used a den over a number of consecutive days, each time it entered the den to rest for the day was counted as one occurrence.

Cameras were deployed at the 15 dens for a total of 2,645 camera nights and recorded 80 spotted skunk detections for an overall detection rate of 3.0/100 camera nights (range=0-7), roughly four times the detection rate reported for cameras placed on fox grids in a separate study (Bolas et al. 2020). Dens were also repeatedly used through time. Two dens monitored for an entire year from May 2018 to June 2019 detected at least one spotted skunk per month in six of the 12 months in one case and eight of the 12 months in another. In addition, multiple individual spotted skunks were observed using the same den over different time periods. In one instance a single den recorded three different individuals at the den entrance within a two-week time frame. Identification of individual spotted skunks based solely on pelage pattern was not possible because unique markings on individual spotted skunks are subtle, images incompletely capture pelage patterns or spotted skunks often moved quickly through the frame creating blurry images. Given that the presence or absence of a collar was the only way to reliably distinguish individuals, the number of different individuals using a den is likely an underestimate.

These results suggest that placing remote cameras at den sites may be an effective way of monitoring spotted skunks through time. However, it may be challenging to tell individuals apart without a distinct feature such as a collar. Spotted skunk dens are also challenging to find without collaring and tracking individuals which may be expensive, time consuming and invasive. Regardless, continuing den monitoring may provide further insights into how prevalent disturbance by foxes or intraguild predation might be, especially in terms of spotted skunk kit survival.

CAMERA SCENT STATIONS

Numerous studies on mainland spotted skunks have used fish or fish scent as a trapping attractant (Hackett et al. 2007, Lesmeister et al. 2009, Sprayberry and Edelman 2018). We tested a fish lure (Pressed Fish Oil, Murry's Lures and Trapping Supplies, West Virginia) using a paired design by baiting camera-trap stations either with or without the scent lure. To increase potential for encounters, scent station pairs were placed in locations near telemetry points from VHF collared spotted skunks that were tracked during the course of this study. Due to equipment limitations, only six scent station pairs were deployed across the island and the length of time a station was in the field varied depending on site (range = 19-52 days). Natural clearings were chosen as locations for each pair to limit the amount of disturbance necessary to allow cameras to record activity at each station.

Each individual scent station consisted of a 17-inch tall white PVC pipe and a removable cap with 4 holes drilled at the top. A single cotton ball was secured inside the top of every PVC pipe. If the station was scented, the cotton ball was completely saturated in fish oil before being placed within the PVC. The unscented station also received a cotton ball. The PVC was placed upright, zip tied to a rebar stake that was secured in the ground. These encased scent stations were determined to be the best form of deployment in the field for the attractant as the scent lure was protected from the elements and wildlife could not dig it up or drag it away. Each scent station within a pair was monitored with a remote infrared camera (Reconyx PC800, MR5 or Browning Dark Ops) set at Medium-High sensitivity to capture 3 frames per second when triggered with a one second delay between triggers. Every 14 days, the control and scented stations (both PVC and rebar) at each scent station site were reversed (i.e. the control would become the scented station and the scented station would become the control) to account for any bias due to location of individual stations

Images that detected an animal were sorted by species. Interaction between the animal and the scent station was noted. An interaction included one or more of following behaviors: scenting, urinating, or rubbing on the station. Detections were considered separate events when spaced at least 30 minutes apart. Differences in fish and control baited stations were compared using a chi-square contingency test.

Scent stations were active between March-May 2019. There were no differences in number of detections at fish and control scent stations for foxes (Chi^2=14.9, df=5, P=>0.5) or spotted skunks (Chi^2=9, df=5, P=>0.5) (Figure 2.8). Foxes were observed frequently at both scented and non-scented stations. A variety of behaviors were exhibited by foxes interacting with scented and non-scented stations with the most common being marking, rubbing a chin or cheek against the post or standing on hind legs to examine the scent that was located at the top of the post (Figure 2.9 and 2.10). When spotted skunks were detected in proximity of scent stations they typically moved quickly through the frame and did not appear interested in the stations. Only one interaction occurred between a spotted skunk and a scent station which captured a spotted skunk lifting its hind leg and apparently marking the post (Figure 2.11). No interactions between foxes and spotted skunks was observed at the stations.

We discourage using scent stations as ways of attracting spotted skunks to camera sites because the stations often become marking locations for foxes. We did not observe an increase of detections of skunks at cameras by using a scented lure and continued fox marking at these spots could discourage spotted skunks if they limit areas utilized by foxes. Scent stations could also increase interspecific interaction occurrences. If further testing of scent stations is conducted, we recommend suspending lures from overhanging branches which could reduce marking by foxes.

QUESTION 3: IS CURRENT SPOTTED SKUNK ABUNDANCE REPRESENTATIVE OF A RETURN TO PREVIOUS HISTORICAL CONDITIONS?

When overall spotted skunk trap success for this study (1.55%) was compared to historical trap success on Santa Cruz Island, trap success recorded in our study, although low, was almost twice as large as that reported in 1992 (Figure 2.12). On opportunistic trapping lines that were set specifically to target spotted skunks, a total of 19 individual spotted skunks (M=16, F=3) were captured 27 times over the course of the project, yielding an overall trap success of 1.55% over 2,916 trap nights with 1,359 of those traps as available. Five individual spotted skunks were recaptured 1 or more times. The male to female capture ratio was 5.3:1. The majority of the foxes caught in these opportunistic trap lines were released without identifying individuals therefore capture rate was based only on the presence of a fox. Overall capture success for foxes was 50.63%.

We observed slight seasonal trap success differences with higher success during Winter/Spring (December-February & May) trapping periods (1.74%) compared to 2018 and 2019 Summer (June-August) periods (0.9% and 1.45%) (Figure 2.13). Between June-August 2018, two individual spotted skunks were captured twice yielding a trap success of 0.90% for spotted skunks and 72.65% for foxes over 336 trap nights (223 available traps). Between December 2018-February 2019 with the addition of May 2019, 13 individual spotted skunks were captured 18 times yielding a trap success of 1.74% for spotted skunks and 44.07% for foxes over 1,614 trap nights (860 available traps). Between June-August 2019, six individual spotted skunks were captured seven times yielding a trap success of 1.45% for spotted skunks and 53.26% for foxes over 966 trap nights (276 available traps). Trapping methods differed slightly between Winter/Spring (December-February & May) and Summer (June-August) seasons. During the Winter/Spring, traps were closed after being checked in the morning then reset in the late afternoon to avoid the traps filling with foxes, while in the Summer traps were reset after being checked in the morning. Whether this difference is a result of trapping methods or an increase in spotted skunk activity during the winter is yet to be determined.

An important caveat is the sex ratio of spotted skunks captured during this study. Although trap success was slightly higher in this study than that was reported in 1992, the sex ratio of 5.3 males:1 female (n = 19) is concerning. Crooks (1994) reported a 1.3:1 ratio (n = 9) and Jones et al. (2013) reported a 2.8:1 ratio (n = 115). Other spotted skunk studies done on the mainland have also reported male skews in trapping efforts (Neiswenter et al. 2010, Doty and Dowler 2006). It is unknown if a high male bias is representative of the current population, higher activity during the trapping season, or if females are simply harder to capture due to trap wariness or because they remain in areas that are currently unsampled. Currently, little is known about island spotted skunk reproduction and this may remain a challenge if females continue to be captured infrequently. The one adult female that was VHF tracked through the spring did not appear reproductively active upon initial capture or recapture. More data is critically needed regarding spotted skunk parturition sites and female dens.

MONITORING RECOMMENDATIONS

Based on these findings, fox population grids and trapping methods are specific to foxes and may not adequately sample areas that are used by spotted skunks. We suggest that future live-trapping or camera trapping protocols include areas with a combination of high slope and high vegetation cover in order to better understand skunk abundance in these areas. Spotted skunk trapping success and camera detections were higher in the late fall and winter so increased efforts during winter should be considered. GPS and VHF collars were found to be valuable monitoring tools; however, we warrant caution that there are challenges of collaring spotted skunks (refer to Appendix 1 for detailed description collar recommendations). We recommend prioritizing mortality collars on spotted skunks to examine cause-specific mortality factors.

We discourage the use of scented stations to attract spotted skunks because repeated markings by foxes at both scented and non-scented stations appear to turn the posts into latrine sites that may be a deterrent to spotted skunks and might increase interspecific encounters. Our comparison of cameras traps placed in drainages and ridgetops suggest that cameras placed in drainages may be more effective at detecting spotted skunks. We also encourage future island spotted skunk studies to consider conducting camera monitoring at known spotted skunk den sites both to examine interactions between foxes and spotted skunks at these sites and as a means of monitoring spotted skunk activity and abundance throughout the year.

Increased trap success of spotted skunks during the late 1990's and through the 2000's may have represented niche expansion as a result of competitive release, with spotted skunks moving into areas of low slope and low vegetation cover. We hypothesize that in the face of current competition as fox numbers increase, spotted skunks are retreating back into their realized niche thus resulting in capture levels similar to those reported in the early 1990's. If this hypothesis is true, two implications arise. First, spotted skunk monitoring would be more effective in areas that represent the realized niche (high slope and high cover density) and in seasons other than the summer which is when spotted skunk trapping success and camera detections are at the lowest. Second, the low spotted skunk densities reported in the literature and recorded in the early 1990's and in the current study may represent the pattern of relative abundance that was typical over the history of the island, and the dramatic decrease in trap success recorded on fox grids over the past decade may represent a return to an historic equilibrium state.

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FIGURES

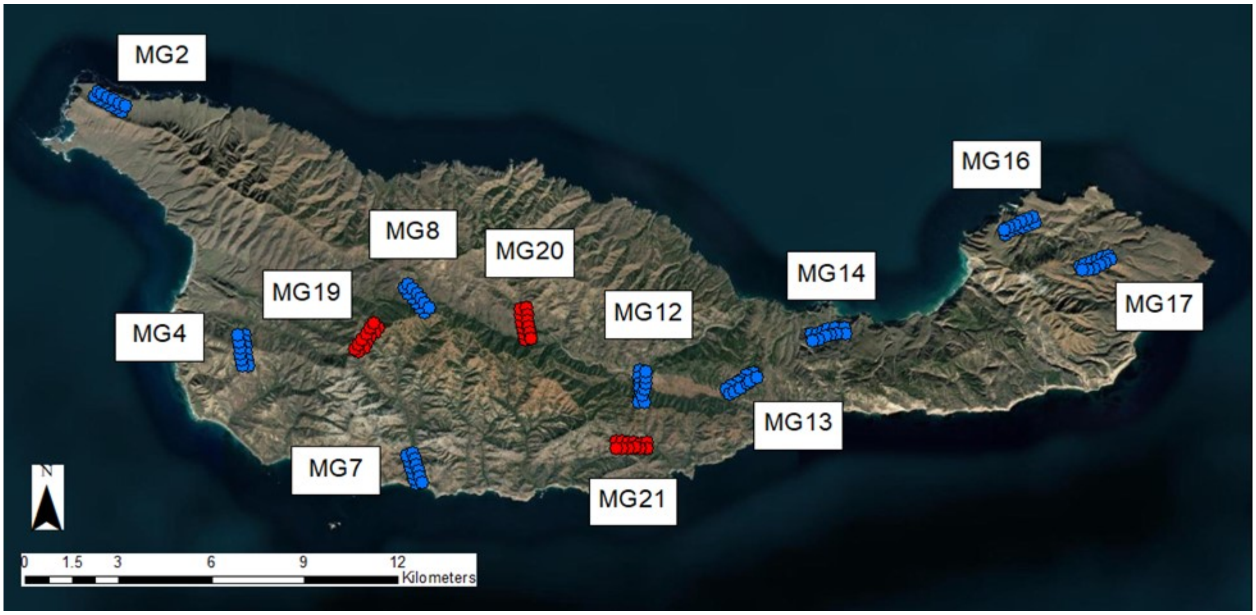


Figure 2.1: Location of 12 fox monitoring mini grids (MG) used on Santa Cruz Island from 2008-2019. Blue grids have been in use since 2008, red grids were added in 2015.

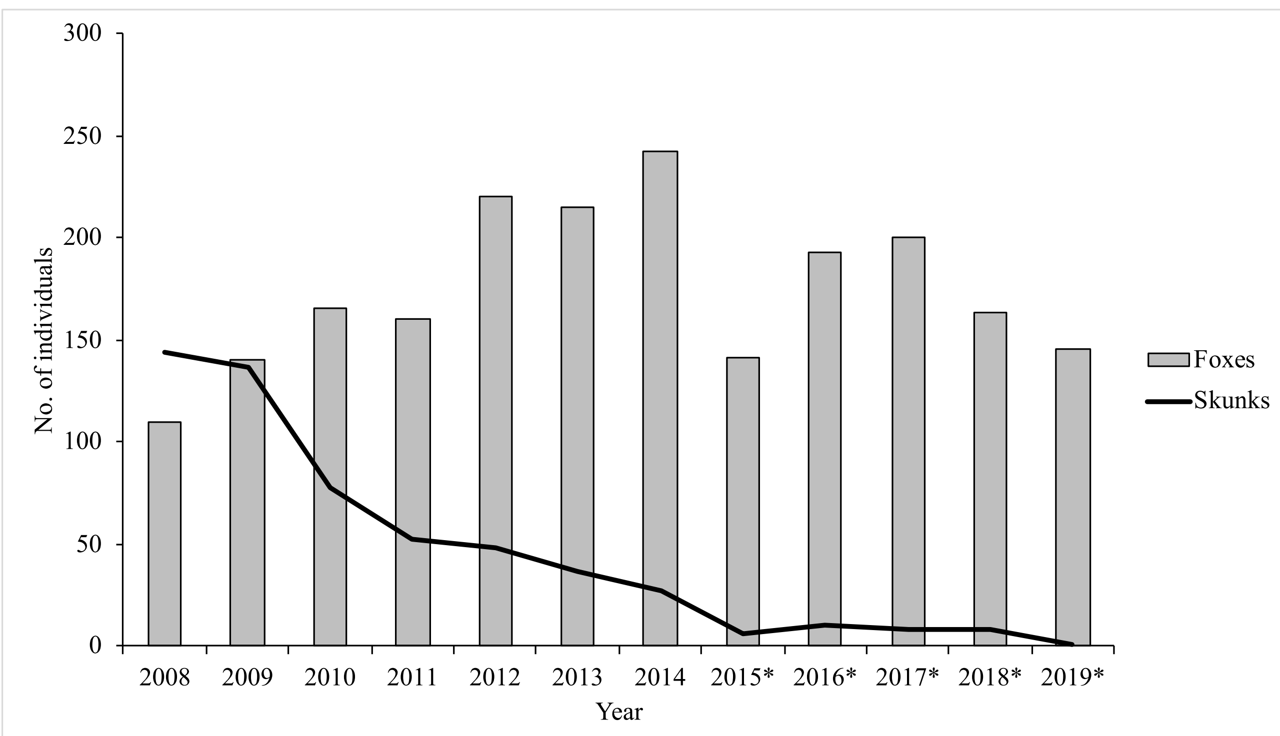


Figure 2.2: Total individual foxes and spotted skunks captured on fox monitoring grids from 2008-2019 on Santa Cruz Island, CA (Dillon et al. in prep). Only one individual spotted skunk was captured in 2019. From 2008-2014 a total of 18 grids were monitored. *In 2015, nine of the original grids were removed and three new grids were added to the trapping scheme.

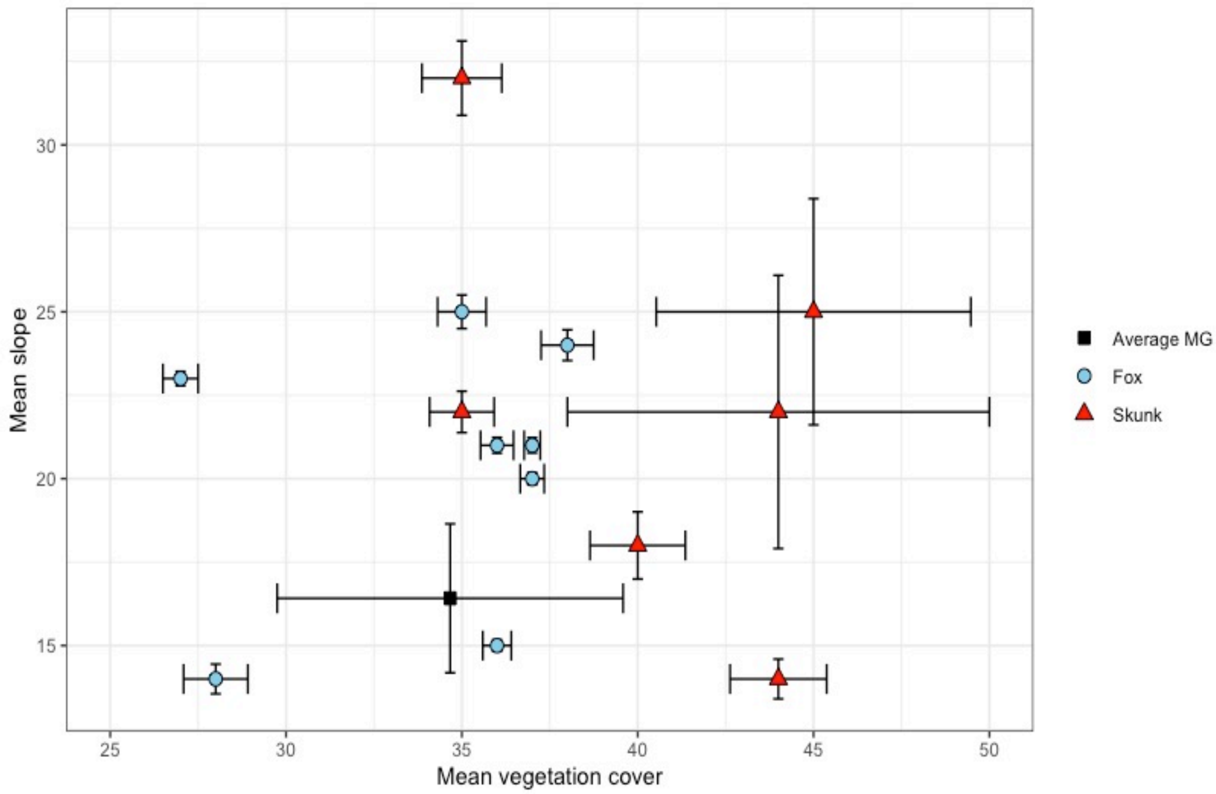


Figure 2.3: Mean (+ SE) slope and vegetation cover for eight GPS collared foxes (red triangle) and six GPS collared spotted skunks (blue circles) in relation to the average fox monitoring grid (black square) on Santa Cruz Island, CA.

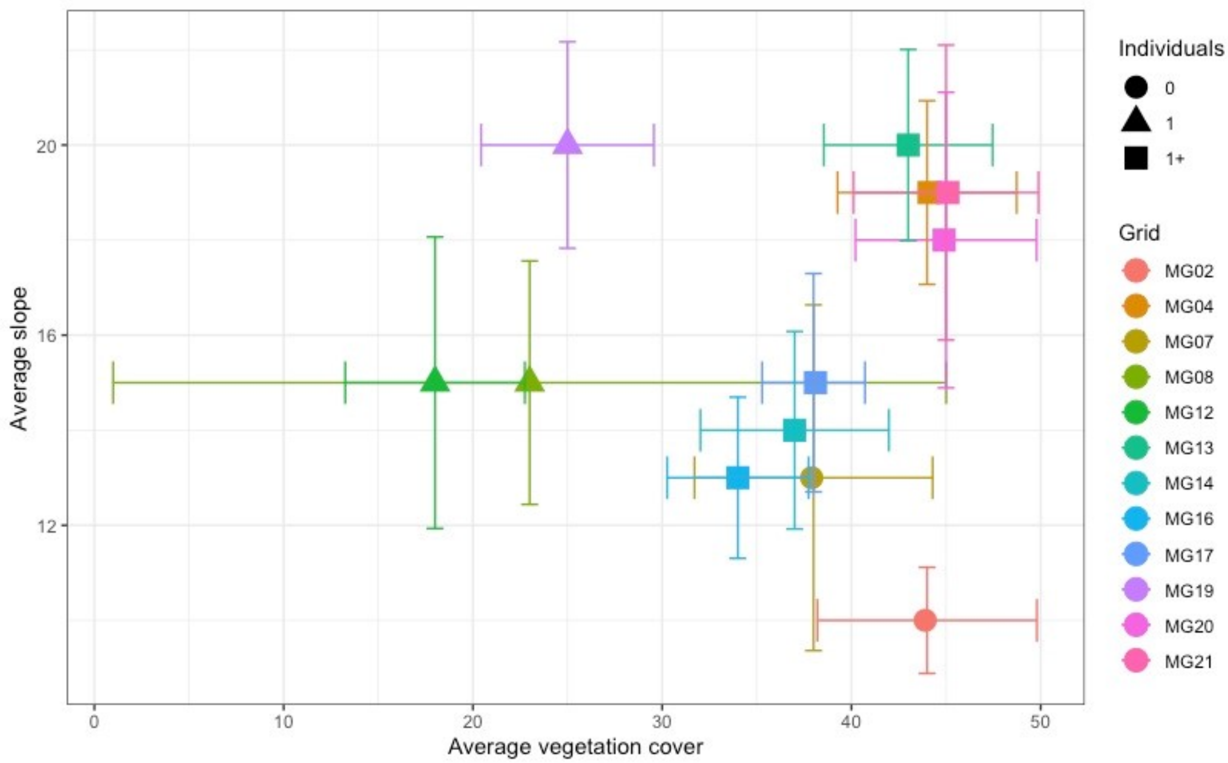


Figure 2.4: The average slope and vegetation cover for each of the 12 fox monitoring grids on Santa Cruz Island, CA in comparison to the number of individual spotted skunks captured between 2015-2019. A circle designates that no spotted skunks were captured on that grid, a triangle represent one individual spotted skunk capture and square represents more than 1 capture. Standard error bars are shown.

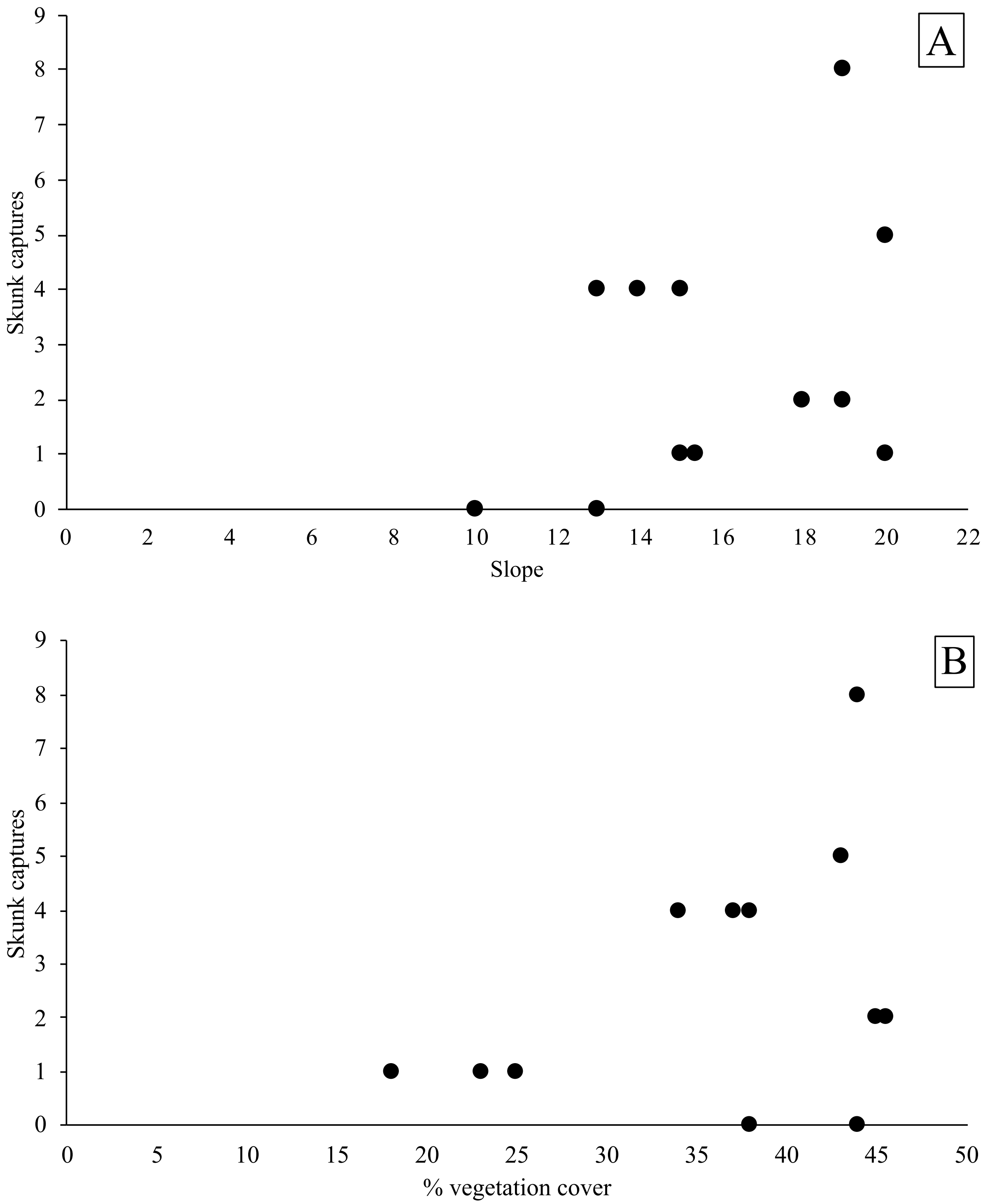


Figure 2.5: Island spotted skunk captures associated with average (A) slope and (B) percent vegetation cover of each fox population monitoring grid on Santa Cruz Island, CA. Multiple regression suggested that average vegetation cover and slope of a monitoring grid did not predict the number of spotted skunks captures (R^2=0.277, P=0.233).

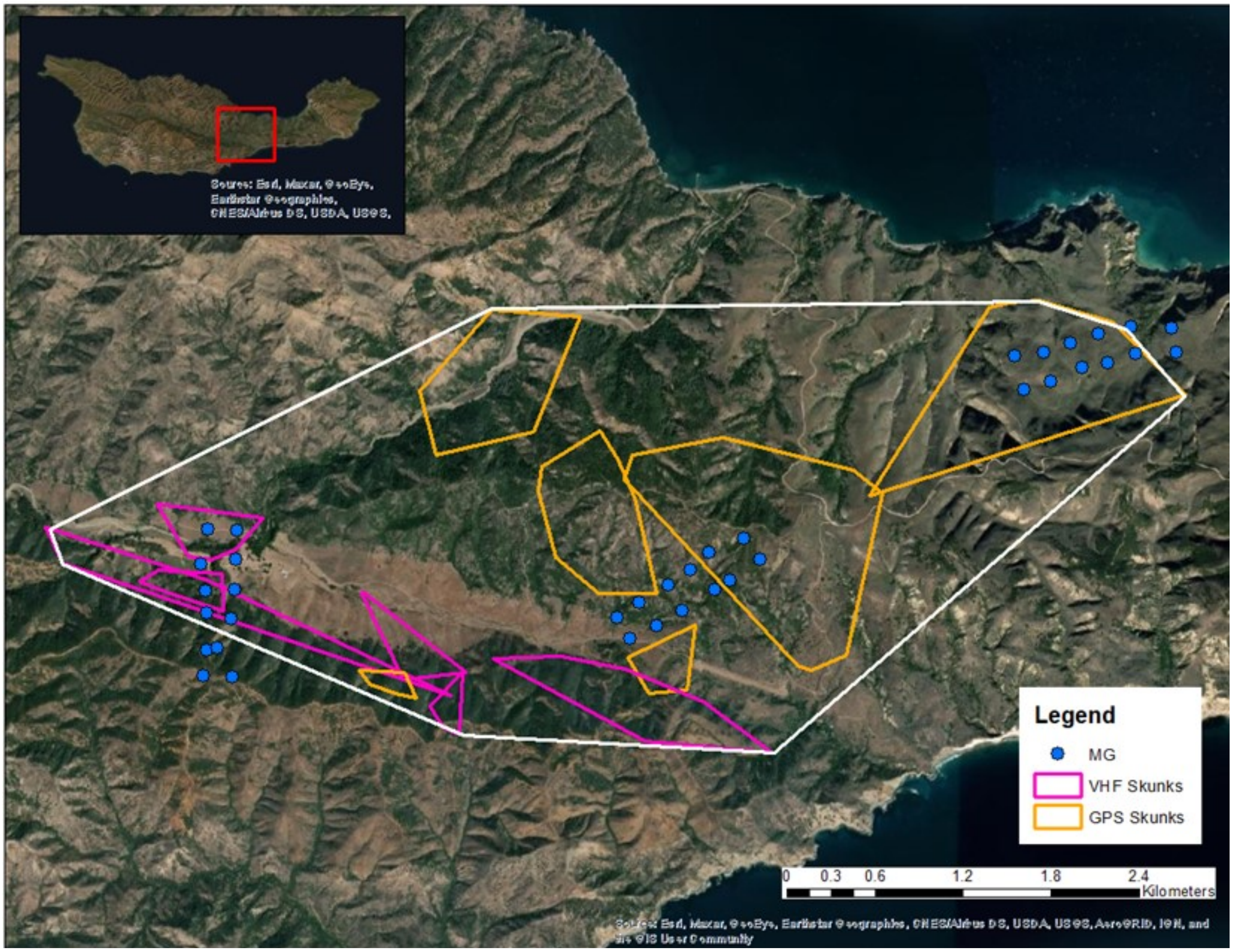


Figure 2.6: Minimum convex polygon home range estimates for six GPS (orange) and six VHF collared (pink) spotted skunks that were in proximity to 3 fox monitoring grids (blue circles) on Santa Cruz Island, CA. The area of the white polygon (1,554 ha) encompasses all collared spotted skunk home ranges. In 2019, no spotted skunks were captured on these grids.

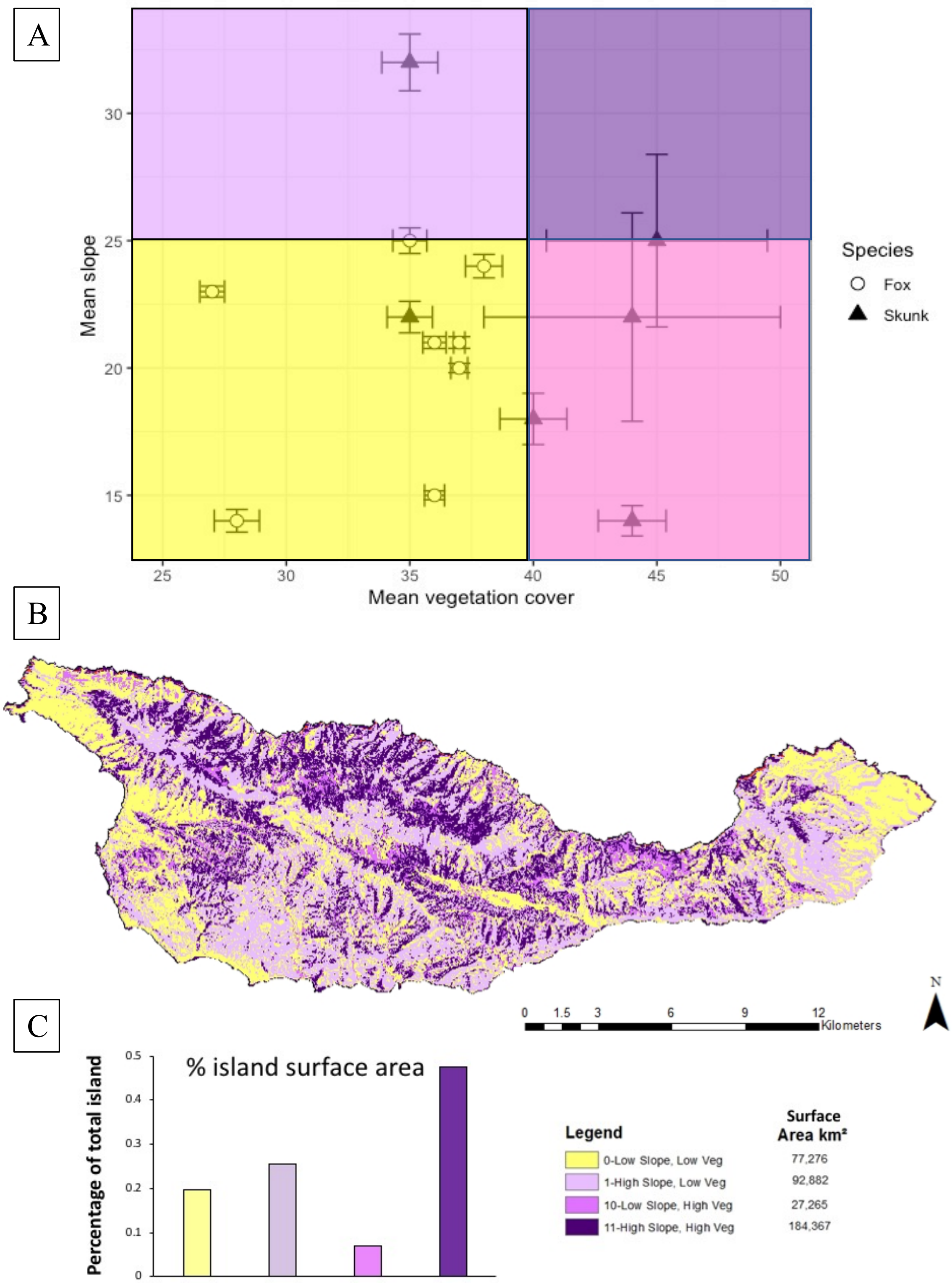


Figure 2.7: A) Characterized values for all GPS collared island foxes and island spotted skunks as one of four slope/vegetation cover categories. B) Map of Santa Cruz Island classifying areas of slope and percent vegetation cover values. C) Percentage of island surface area for each category.

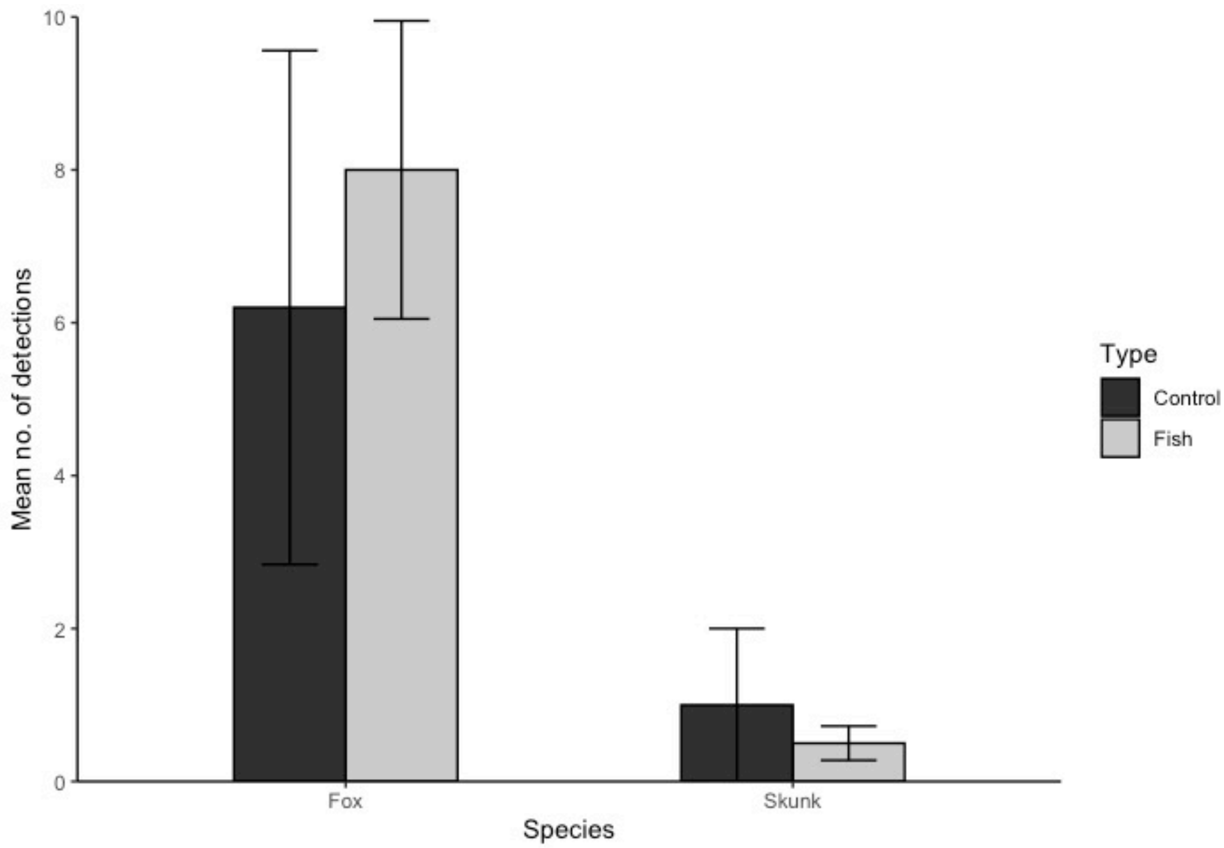


Figure 2.8: Mean number of island fox and spotted skunk detections at scented (fish oil) versus non-scented (control) cameras stations on Santa Cruz Island, CA. Standard error bars are shown. There were no differences in detections between fish and control scent stations for foxes (R^2=14.9, df=5, P=>0.5) or spotted skunks (R^2=9, df=5, P=>0.5).

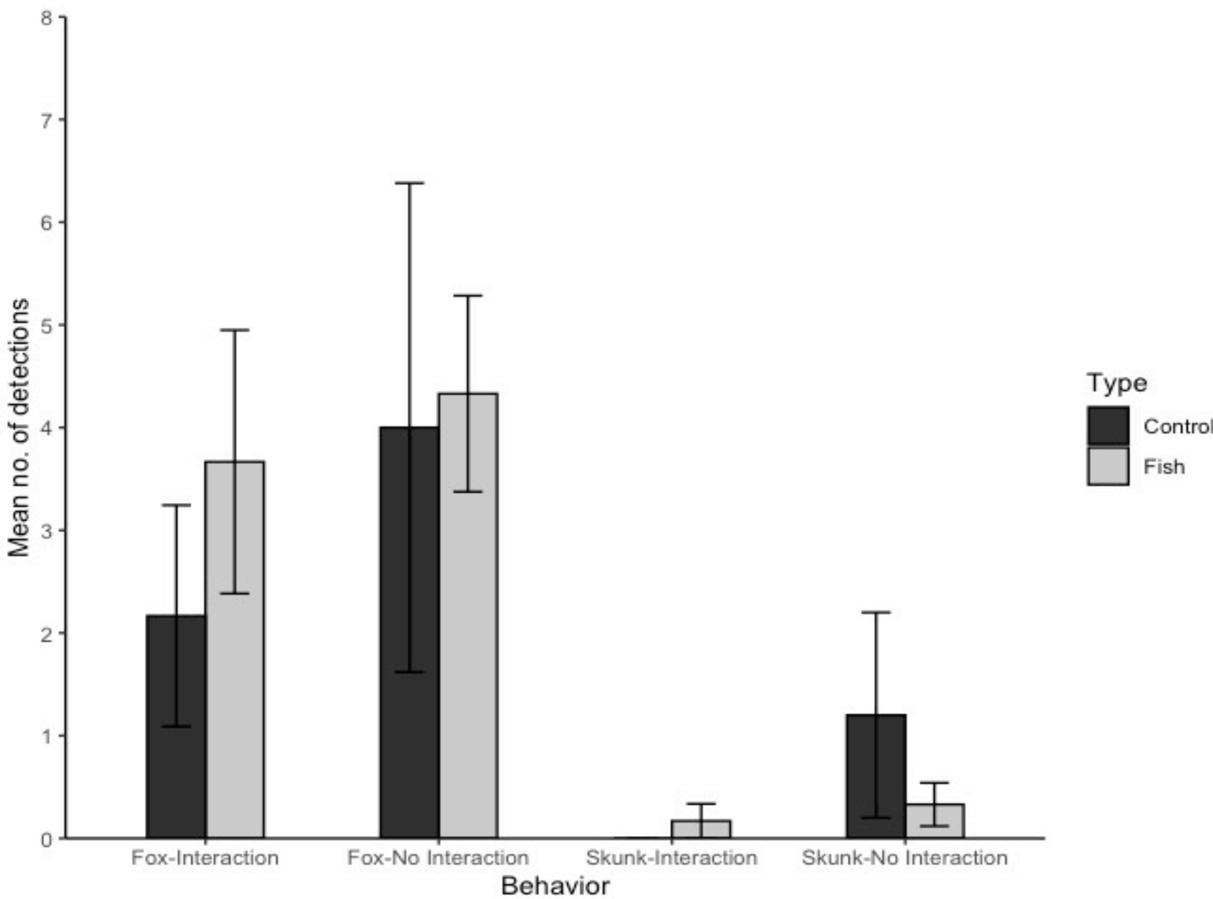


Figure 2.9: Interaction versus no interaction of island foxes and spotted skunks at scent stations on Santa Cruz Island, CA. Standard error bars are shown.

Figure 2.10: Island fox behaviors observed at scent stations placed on Santa Cruz Island, CA which included A) scenting, B) marking, and C) cheek/chin rubbing.

Figure 2.11: Island spotted skunk behaviors observed at scent stations placed on Santa Cruz Island, CA. The photo on the left shows a spotted skunk moving quickly through the frame, showing no interest in the station, a behavior most frequently seen at a station. The photo on the right shows the only occasion of a spotted skunk interacting with a station-this individual is thought to be marking the post

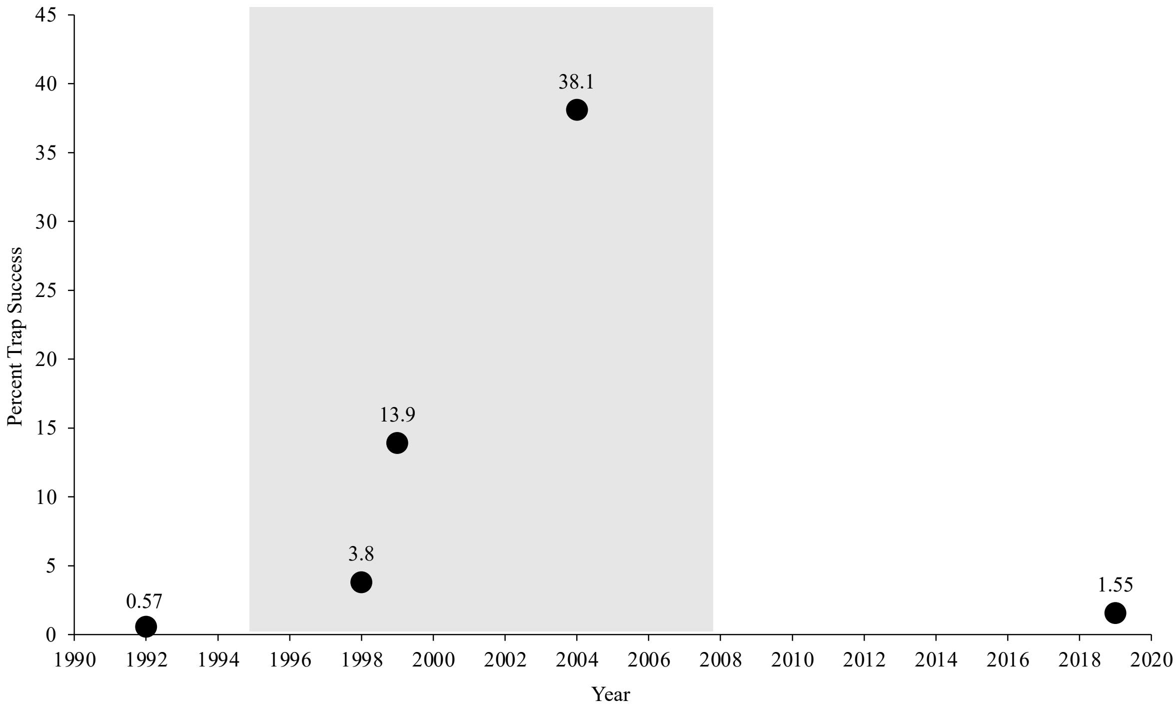


Figure 2.12: Island spotted skunk opportunistic trap success from various projects conducted on Santa Cruz Island, CA from 1990-2019 (Crooks 1994, Crooks and Van Vuren 2000, Roemer 2002 and Jones et al 2008). The gray box represents the approximate timeframe of the decline and recovery of island foxes.

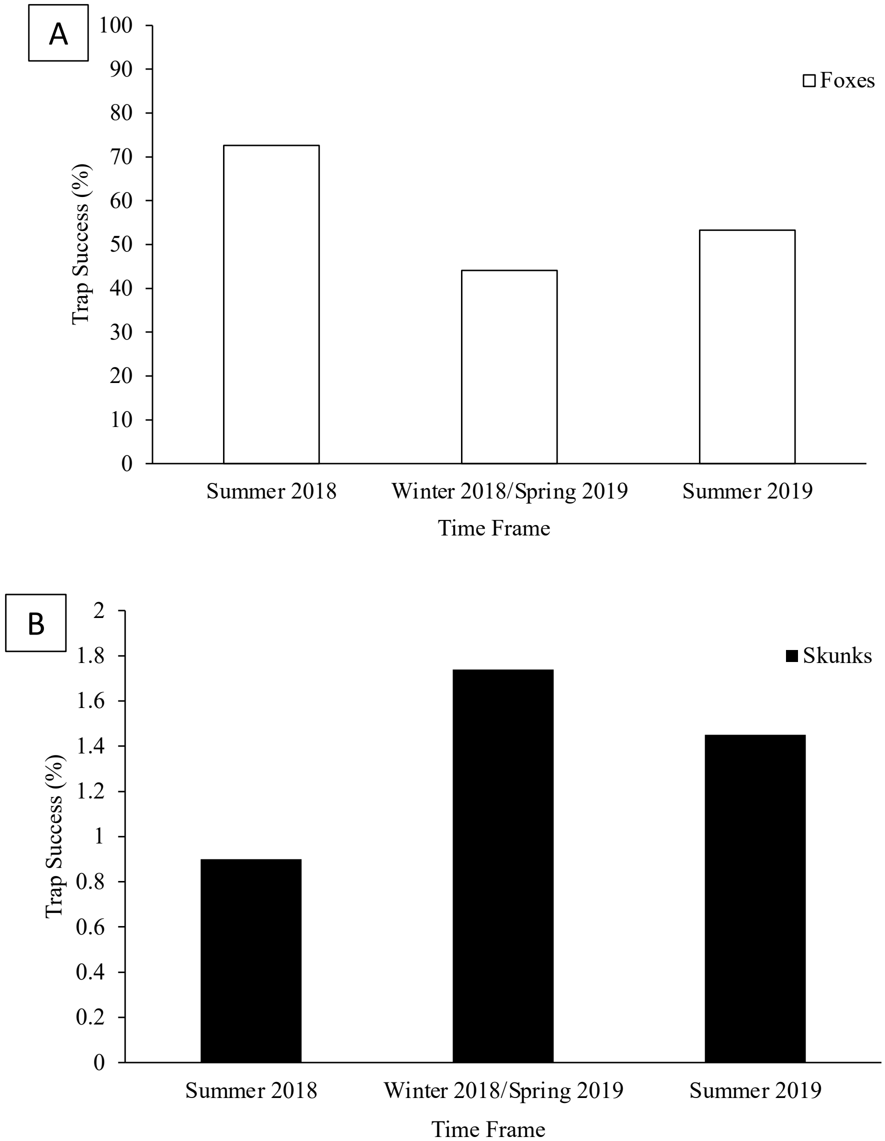
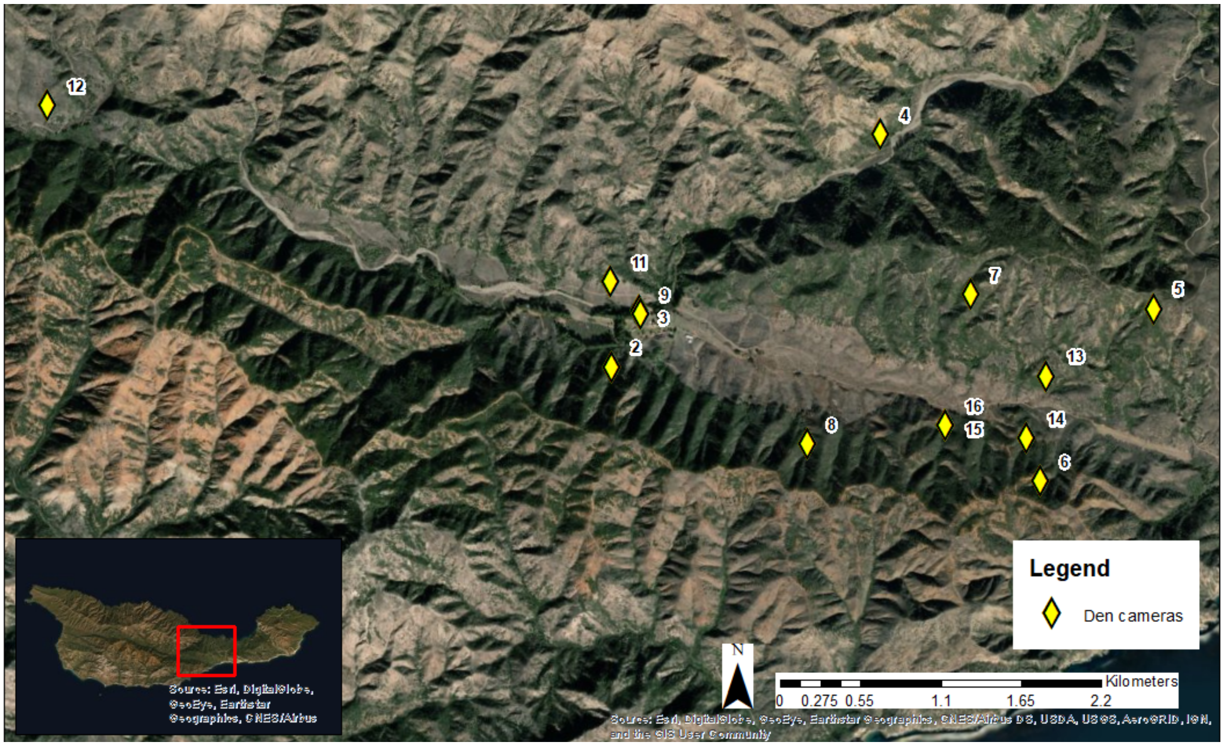
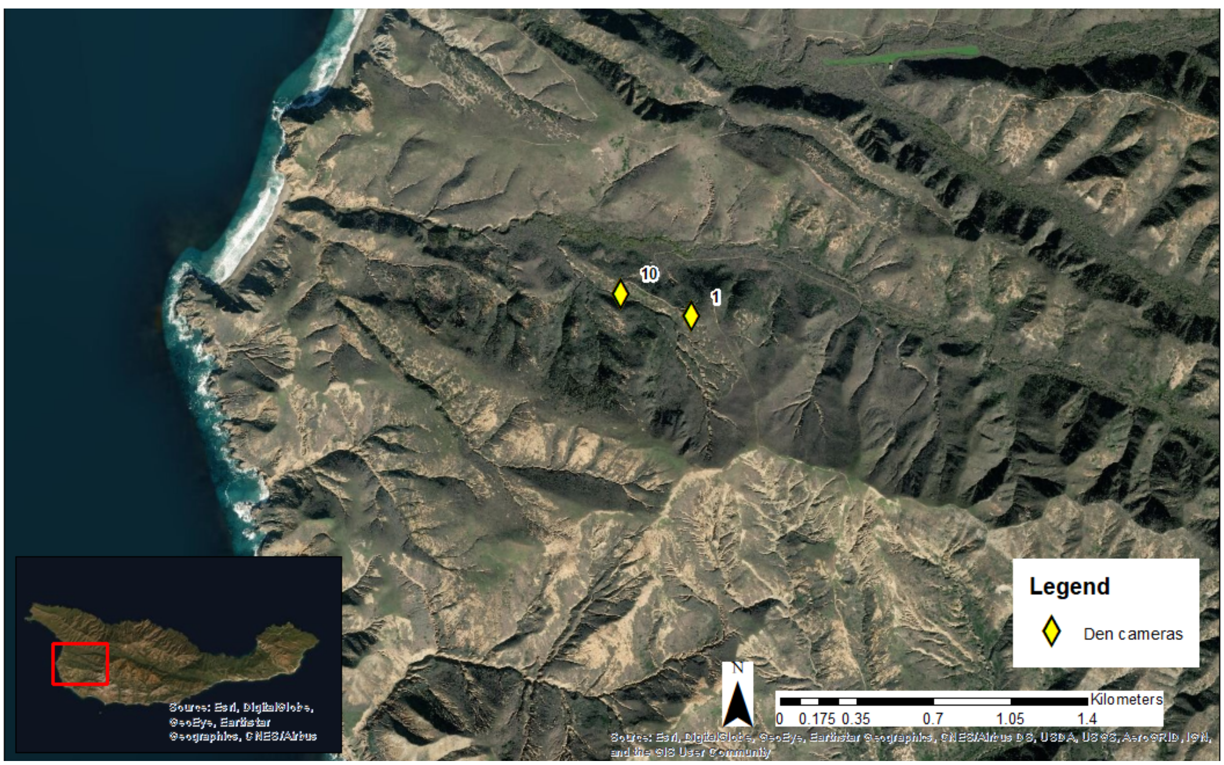


Figure 2.13: Trap success for A) foxes and B) spotted skunks conducted during three different time frames over the course this study.





Appendix A: Location of island spotted skunk dens monitored using remote cameras on the west (top) and central valley (bottom) of Santa Cruz island, California.

Camera ID	Days in field	Slope	Vegetation Cover	Fox visitation rate	Skunk visitation rate
1	93	17	55	0	0.011
2	213	34	45	0.446	0.038
3	70	5	0	1.242	0.014
4	75	15	54	0.013	0
5	253	9	55	0.024	0.056
6	361	43	35	0.188	0.064
7	104	32	30	0.029	0.058
8	177	34	30	0.005	0.062
9	6	9	30	0.167	0
10	189	32	65	0.005	0.085
11	46	21	55	0.065	0.022
12	27	21	55	0.037	0.074
13	152	31	35	0.007	0.066
14	137	28	45	0.036	0.066
15	91	16	45	0.011	0.033

Appendix B: Island fox and spotted skunk visitation rates at individual skunk den sites.

ID	Sex	Months monitored	Tracking Points	Home Range
168.682	F	Feb-May	22	48.97
168.072	M	Jan-Mar	10	14.17
168.108	M	Jan-Apr	7	15.16
168.161	M	Feb-May	21	89.98
168.469	M	Feb-May	26	9.25
168.701	M	May	7	5.05
168.831	M	Feb-May	20	40.79
168.952	M	Jan-Mar	16	15.81
Average Male			**15.28**	**27.17**
SE			**2.82**	**11.32**
All Skunks			**16.13**	**29.90**
SE			**2.59**	**10.18**

Appendix C: Monitoring timeframe, number of points used in home rang estimate and home range size in hectares estimated using 100% MCP for eight VHF collared spotted skunks on Santa Cruz Island, CA.

ID	Sex	Months Monitored	GPS Points	Home Range
Skunk31259	M	Aug-Nov	20 (133)	159.31 (78.48)
Skunk31260	M	Jul-Nov	29 (179)	196.33(138.21)
Skunk31269	M	Jul-Mar	49 (238)	298.99 (169.04)
Skunk31270	F	Dec-Mar	16 (105)	139.65 (84.12)
Skunk31271	M	Jan-Feb	5	N/A (3.96)
Skunk31273	M	Jan-Feb	5	N/A (13.09)
Average Male			**21.60 (112.00)**	**218.21 (80.56)**
SE			**8.24 (46.75)**	**41.78 (32.85)**
Average Skunk			**20.67 (110.83)**	**198.57 (81.15)**
SE			**6.80 (38.19)**	**35.48 (26.82)**

Appendix D: Monitoring timeframe, number of points used for home range estimates and home range size in hectares for six GPS collared spotted skunks on Santa Cruz Island, CA. Shown outside the parenthesis are values associated with 95% KDE while values in parenthesis are associated with 100% MCP. Only rolling points were used in the calculation of KDE, while all points within the timeframe were used for MCP.

ID	Sex	Months Monitored	GPS Points	Home Range
Fox31400	F	Aug-Dec	252 (1,117)	31.54 (49.48)
Fox31401	F	Aug-Oct	152 (459)	39.29 (29.75)
Fox31402	M	Aug-Feb	330 (1,425)	50.13 (76.02)
Fox31403	M	Aug-Nov, Mar-Aug	494 (2,319)	73.53 (356.95)
Fox31404	M	Aug-Nov	171 (463)	71.66 (103.27)
Fox31405	F	Aug-Jul	615 (2,972)	64.54 (113.14)
Fox31406	M	Aug-Oct	199 (472)	58.54 (48.66)
Fox31407	M	Aug-Jul	648 (2,925)	106.79 (143.71)
Average Male			**368.4 (1,520.80)**	**72.13 (145.72)**
SE			**90.30 (491.78)**	**9.67 (55.09)**
Average Female			**339.67 (1,516.00)**	**45.12 (64.12)**
SE			**140.66 (752.37)**	**9.96 (25.16)**
Average Fox			**357.63**	**62.00**
SE			**71.13 (383.44)**	**8.28 (37.08)**

Appendix E: Monitoring timeframe, number of points used for home range estimates and home range size in hectares for eight GPS collared foxes on Santa Cruz Island, CA. Shown outside the parenthesis are values associated with 95% KDE while values in parenthesis are associated with 100% MCP. Only rolling points were used in the calculation of KDE, while all points within the timeframe were used for MCP.

	ID	GPS pts used	Average slope	Average % vegetation cover
All points	Skunk31259	133	32	35
	Skunk31260	179	14	44
	Skunk31269	238	22	35
	Skunk31270	105	18	40
	Skunk31271	5	22	44
	Skunk31273	5	25	45
	Avg Skunk	**110.83**	**22**	**40.5**
	SE Skunk	**38.19**	**1.80**	**2.54**
	Fox31400	1120	23	27
	Fox31401	459	24	28
	Fox31402	1426	21	26
	Fox31403	2319	21	37
	Fox31404	463	25	35
	Fox31405	2978	20	37
	Fox31406	472	14	28
	Fox31407	2926	15	36
	Avg Fox	**1520.38**	**20**	**34.25**
	SE Fox	**383.85**	**0.31**	**0.54**

Appendix F: Average degree slope and percent vegetation cover for 8 island foxes and 6 spotted skunks based on all data points collected from GPS collars. Timeframe of data varies depending on individual.


Appendix G: Island spotted skunk den site associated with human-made log piles on Santa Cruz Island, CA. The telemetry receiver is shown for scale.

Appendix H: Examples of spotted skunk den sites associated with Eucalyptus trees on Santa Cruz Island, CA. The telemetry receiver in the photos was placed closest to where the VHF signal from the skunk was strongest.

Appendix I: Collaring Summary and Recommendations

In February and April 2019, aerial flights and extensive ground searches were conducted to listen for VHF signals and download data, but the pilot and ground personnel were unable to locate the majority of the collars. Recovery of most of the data occurred by setting traps for the animals based on initial capture site or where they were believed to be spending time. By the end of summer 2019, personnel were able to physically recover six out of the eight fox collars and three out of the ten spotted skunk collars. Similar damage was observed on the collars, in that all were missing antennas. Majority of the fox collars were covered with bite marks, and a few were missing connector prongs and GPS unit entirely. During this study, the VHF signal from over half of the GPS collared spotted skunks was never heard during telemetry surveys. These individuals were never captured again, and it is unknown what happened to the spotted skunks or the collars.

Partial datasets from 14 individuals (eight foxes, six spotted skunks) were acquired either through remote download or physical capture. Overall GPS fix success rate was 87 ± 4% for fox collars and 64 ± 9% for spotted skunk collars. Total successful fixes for was 13,829 out of 16,533 fix attempts for all fox collars (M=5, F=3) and 757 out of 1,243 fix attempts for all spotted skunk collars (M=5, F=1). We collected 131 ($\bar{x}$ =15 ± 3) telemetry locations between February-May 2019 for 9 VHF collared spotted skunks (M=8, F=1). Inclement weather and road closures prevented access to all but the central valley of the island for the majority of the winter and spring which limited tracking opportunities. Premature collar failures occurred on the majority of VHF collars that were deployed, averaging a life of 64 ± 11 days. Upon recapture of VHF collared spotted skunks, heavy wear was observed on the battery casing and it is hypothesized that exposure to the elements may have caused the battery to fail.

Large scale movement was observed for two (1M, 1F) VHF collared spotted skunks. From 12-15 February 2019 a male spotted skunk moved ~1.9 km, then from 15-17 February an additional ~1.1 km, totaling ~3 km displacement in 5 days. During 4-8 April 2019 a female spotted skunk moved ~1.7 km. These distances are reported as a straight line and do not take into account topography.

For future collaring studies, we recommended collecting data over a shorter amount of time rather than extending data collection over a year long period. Collars were observed to deteriorate quickly over the course of this study therefore it would be most valuable to start data collection immediately. Thus, deploying collars right before the study season of interest is suggested. We also recommend frequent monitoring of the animal to ensure well-being and increasing the amount of data downloads during the study to confirm the collar is functioning properly.

Although GPS collar programming allowed the user to create a customizable GPS, VHF and RF schedules, this flexibility made it easy to create user error when developing and importing the schedule to the collar. Each collar schedule should be carefully examined prior to deployment. In this study GPS, RF and VHF schedules were determined by animal capture location. However, there were a few occurrences where many animals ended up in the same area all of which having the same download schedule. This made it difficult to track and complete all downloads within the allotted time particularly with limited field personnel. When the RF option was functioning, remote downloads completed from the ground was found to be extremely helpful in obtaining data, as skunks are often hard to recapture in traps.

Remote downloading of data from GPS collars using fixed wing aerial surveys was attempted in this study but was largely deemed unsuccessful. The first attempt at remote downloads in the fall resulted in the pilot only able to fully download data from only four foxes. An observation made by the pilot noted that as time passed and the collar collected more data, a single data file would be very large and would take a considerable amount of time (45+ sec) to download. In order for a successful download to be completed, a constant connection between the collar and the downloading unit is required thus the plane would need to remain in a stable position over the collar over the entire course of the download. In a fixed wing plane this would not be feasible.

Mortality signals are useful in detecting when an animal may have died or slipped its collar, therefore future collaring studies should include mortality options particularly if studies are able to utilize aerial telemetry as a monitoring tool. In our study, order to conserve battery life, GPS collars did not include a mortality feature. Also due to miscommunication with the manufacture, a mortality signal option was also not included with the VHF spotted skunk collars which made determining if a spotted skunk was alive difficult, especially when it consecutively reused the same den site.

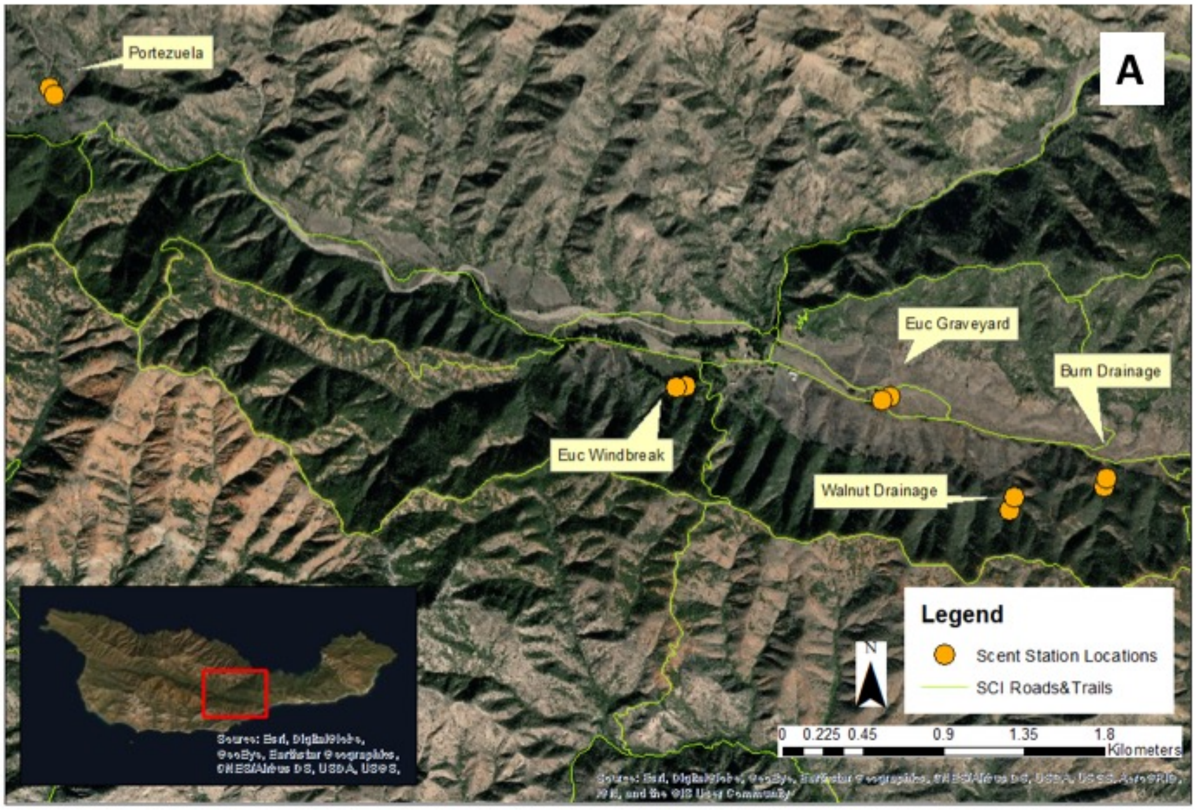
Material and design of future collars should be carefully considered. At the end of the study, all fox and spotted skunk GPS collars that were recovered were observed with damage; all were missing antennas and a two fox collars missing the GPS unit entirely. All VHF/RF signals on the GPS collars were no longer transmitting, however upon collection they were still collecting GPS points. Cause is unknown but may be attributed to antenna loss, therefore considering a collar with a sturdier antenna is suggested. Although the self-assemble VHF skunk collar was lightweight, this design made it difficult and time consuming to fit on the skunk, and the many pieces needed for assembly were easily lost in the field. In the future the use of neoprene buckle attachments for skunk collars is encouraged. Heavy wear was also observed on the battery casing on all of the recovered VHF skunk collars and it is likely that exposure to the elements may have affected the life of the battery which caused all the collars to fail prematurely. This wear may have been caused by skunks going in and out of dens, therefore, this portion of the collar should be covered with thicker epoxy to prevent the internal hardware being exposed.

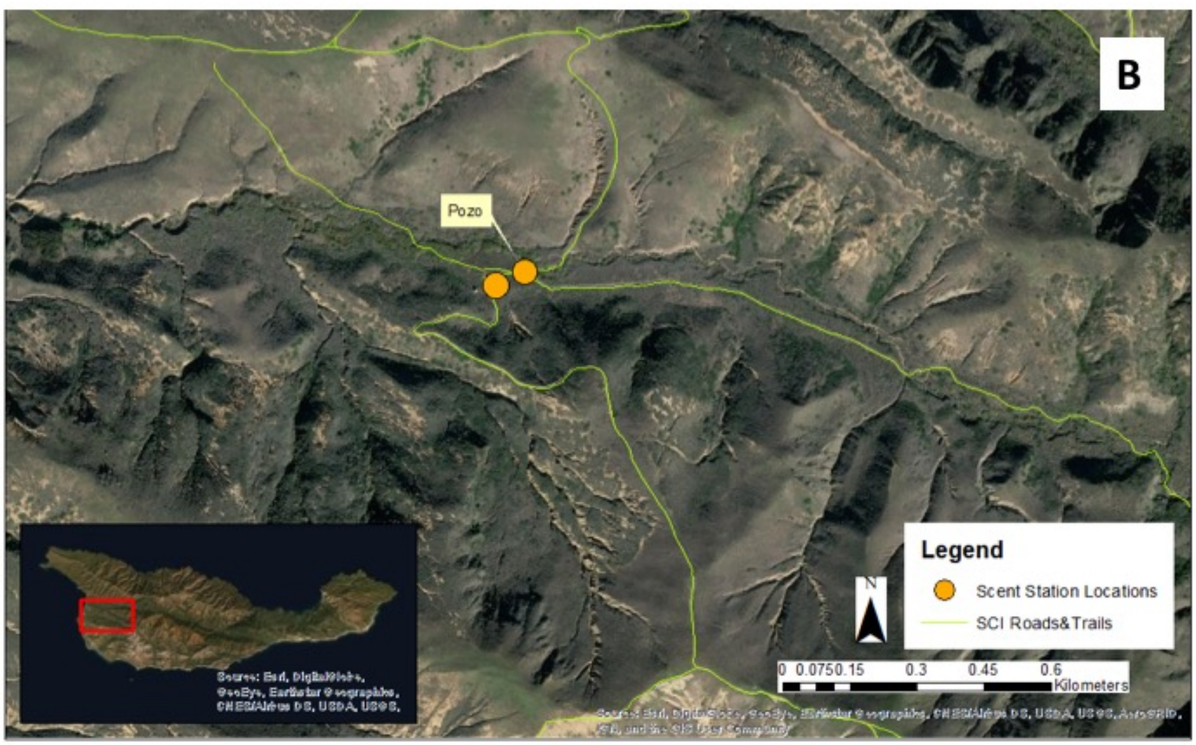
Success rate for valid fixes on spotted skunk GPS collar was 64 ± 8.95% compared to fox collars 87 ± 4.40%. This could largely be due to skunks frequently utilizing underground den sites and dense vegetation which limit satellite connection. An eastern spotted skunk GPS collaring study that also used the same brand and model of collar as this study reported a similar success rate of 62% for valid fixes and noted that a fix was never obtained when a skunk was inactive and likely in a den (Arts, 2020).

Appendix J: Island spotted skunk GPS collars upon deployment (top) and collection (bottom).

Appendix K: Island fox GPS collars upon deployment (top) and collection (bottom).

Appendix L: Island spotted skunk VHF collars upon deployment (top) and collection (bottom). The top right photo shows the addition of an accelerometer device attached by researchers for a separate study.





Appendix M: Location of paired scent stations in the A) central valley and B) west end of Santa Cruz Island, CA.