



Island Fox Recovery Program

2009 Annual Report

Natural Resource Report NPS/MEDN/NRR—2010/235



ON THE COVER

Female island fox 86401, San Miguel Island, 1994
Photograph by National Park Service

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Executive Summary

In 2009 the National Park Service continued to implement recovery actions for endangered island fox subspecies on San Miguel Island (*Urocyon littoralis littoralis*) and Santa Rosa Island (*Urocyon littoralis santarosae*). A 10-year program of captive breeding and release of both subspecies had been completed in 2008. The San Miguel captive breeding facility had been closed in 2007, and the Santa Rosa captive facility was closed in 2008 after the final release of captive foxes in November. Island foxes had been removed from the wild for captive breeding on San Miguel in 1999, and on Santa Rosa in 2000. During the 10-year captive breeding program, 138 pups were born in captivity, and 155 foxes were released to the wild, beginning in 2003 on Santa Rosa and 2004 on San Miguel. Excellent reproduction in the wild, exceeding the per capita reproduction in captivity, was the primary reason to cease captive breeding. Also, predation by golden eagles (*Aquila chrysaetos*) had been almost completely mitigated during the 10-year time period, and wild island fox survival rose to 80–90% on both islands. The excellent survival and reproduction in the wild allowed rapid growth of the small, recovering populations, and by the end of 2009 the San Miguel island fox population estimate was 256 adults and 318 total foxes, and 187 adults and 389 total foxes for Santa Rosa (Figure 1). The park's island fox program has entered an intensive monitoring phase to insure that recovery continues apace, and to eventually document attainment of criteria which would allow delisting of the two subspecies.

Annual survival of released and wild-born foxes continued to be high on San Miguel (93%), and only four radio-collared foxes died on San Miguel in 2009, none from eagle predation. For the third consecutive year, annual survival on Santa Rosa (84%) remained above 80%. Nine radio-collared foxes died on Santa Rosa in 2009, and four of those mortalities were due to predation. In several cases predation was incomplete; i.e., the carcass was not consumed. Other mortality factors included 2 cases of asphyxiation, one due to the collapse of a den on San Miguel, and the other due to entrapment in a pipe on Santa Rosa. Another Santa Rosa fox died when its radio collar became entangled on the branch of a shrub.

In spring 2010 golden eagle predation decreased island fox annual survival on Santa Rosa Island to 61%. Eleven radio-collared Santa Rosa foxes died from predation in February–April 2010. Golden eagle feathers were found at two mortality sites, and three golden eagle sightings were recorded on Santa Rosa during that time period. Two helicopter survey/capture operations, one in March and one in April, recorded no golden eagles on the island.

We conducted grid trapping in summer–fall 2009 to monitor the wild populations on each island. On San Miguel we trapped foxes on four small grids, in order to estimate fox density, replace radio collars, gauge reproduction through capture of pups, vaccinate wild foxes, and check physical conditions. A total of 69 individuals were trapped on the grids in 2009. The adult density estimates for the four grids, as calculated with program Density, were 5.4, 7.0, 7.3 and 6.8 foxes/km². Multiplying the average adult density (6.6 foxes/km²) by the island area (38.1 km²) yielded a population estimate of 256 adult foxes. When pups were included in density estimations, the total island-wide population was 318 foxes. Since reintroductions began in 2004, the average annual rate of increase (λ) was 1.68 for the San Miguel island fox population.

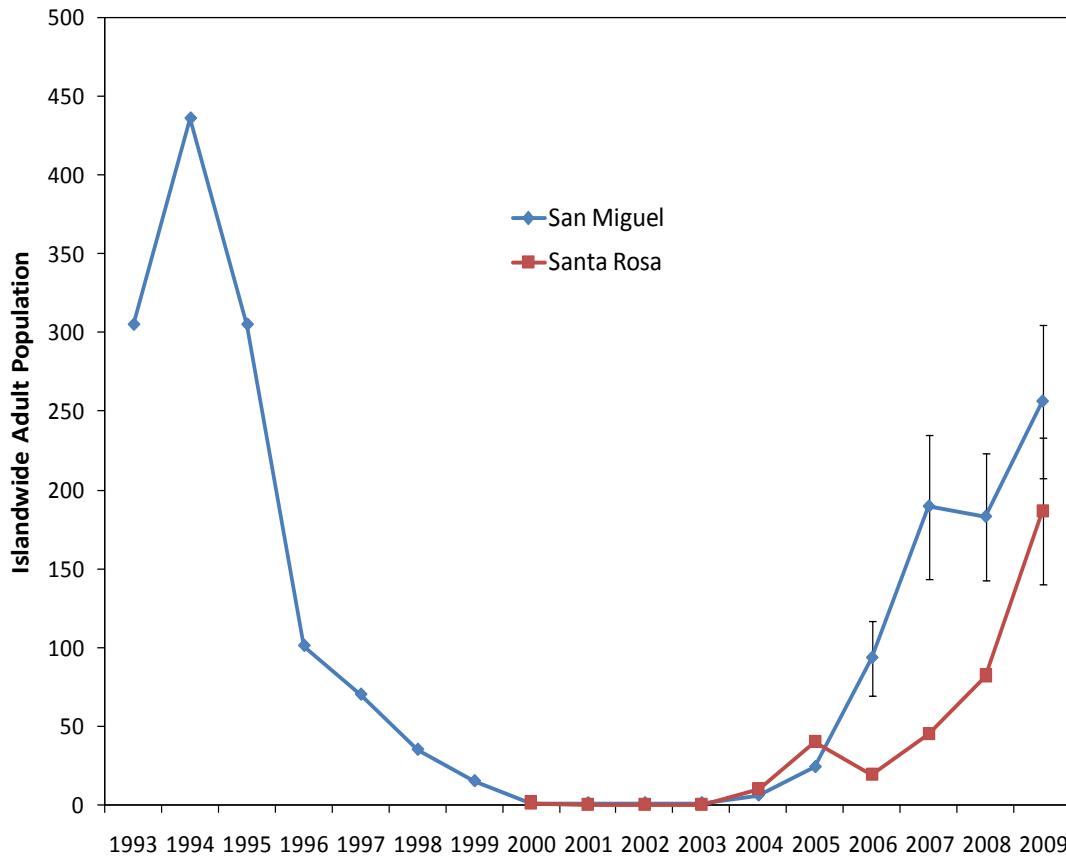


Figure 1. Estimated number of adult island foxes for San Miguel and Santa Rosa. Pre-decline estimates are not available for Santa Rosa; 80% confidence intervals shown for estimates from program DENSITY.

A total of 21 wild-born pups were caught on the San Miguel grids during fall trapping. Reproductive success was estimated as the number of grid pups divided by the number of adult females caught on the grids ($n = 25$). The estimated reproductive success of 0.84 pups per female was lower than that in previous years, likely due both to reduced reproductive effort at higher densities, and the effects of recent drought conditions on resources available for reproduction.

In previous years, trapping on Santa Rosa had been conducted on transects, which precluded estimation of density and island-wide population size. In 2010 we conducted trapping on 18 small “ladder” grids, as recommended by Rubin et al. (2007). Average density on the 18 grids was 0.86 foxes/km², and multiplying that by the island area (216 km²) produced an adult density estimate of 187. Including pups in the analysis resulted in an island-wide population estimate of 389 foxes. To estimate reproductive effort, we used the number of pups recorded on both the trapping grids and transects used to manage radio collars and vaccinate foxes. The reproductive effort was 1.12 pups/female (47 pups/42 females). The higher reproductive success on Santa Rosa compared to San Miguel may be due to the lower fox densities on Santa Rosa. The higher reproductive success on Santa Rosa was reflected in the difference between the adult population

estimates and those that included pups for each island; including pups doubled the population estimate for Santa Rosa, but only increased the San Miguel estimate by a factor of 1.2.

As the only other terrestrial carnivores on Santa Cruz and Santa Rosa Islands islands, island spotted skunks (*Spilogale gracilis amphiala*) are competitors with island foxes and increased dramatically on both islands following island fox decline. Because they are caught in traps set for island foxes, annual grid-based monitoring is an opportunity to track the skunk population as island foxes recover. In 2009, for the first time, we were able to estimate the size of the population on Santa Rosa Island, because we marked individual skunks with passive integrated transponder (PIT) tags. We used program Density on skunk capture data from the 18 “ladder” grids to obtain a mean skunk density of 12.3 skunks/km² and an island-wide estimate of 2,649 skunks. The estimate includes both adults and juveniles, which were not distinguished from each other in the field. Thus, skunks were almost 7 times as abundant as island foxes. Even so, relative capture rates from 2009 and previous years indicate that skunks are decreasing as the fox population recovers.

In 2009 we vaccinated foxes against rabies and canine distemper virus. Our goal was to vaccinate all foxes we trapped against both viruses, though we were limited by the number of vaccines we had on hand. Over 90% of trapped foxes were vaccinated against rabies, and over 80% against canine distemper virus. Number of vaccinates for rabies was 104 on San Miguel and 113 on Santa Rosa, while the number of foxes vaccinated against CDV was 110 and 132, respectively.

Acknowledgments

I first thank our outstanding island fox field crew, whose efforts are entirely responsible for the excellent progress we've realized in island fox recovery on the Northern Channel Islands. In 2009 we benefited from the exceptional work of our field crew: Angela Guglielmino, Lisa Drake, Sarah Hansen, Jen Savage, Jim Howard, and Donivan Sphar. They were capably led by supervisory wildlife biologist Helen Fitting.

Rich Block, Alan Varsik, Karl Hill, and the Santa Barbara Zoo continued their generous donation of staff time and expertise to our field program. Pat Meyer and the Friends of the Island Fox have been strong supporters of our fox recovery program, and have purchased radio collars for the program. We also thank Scott Morrison, Lotus Vermeer, and Christie Boser of The Nature Conservancy for making TNC an ideal partner for NPS in island fox recovery, as well as in other resources management efforts on Santa Cruz Island. Dave Garcelon and Brian Hudgens of the Institute for Wildlife Studies remain a great source of assistance and advice in island fox recovery, and Vickie Bakker graciously guided us in our efforts to estimate island fox densities from trapping data. We also appreciate the donation of GPS and proximity collars by Brian Cypher and Kathy Ralls, two cooperators who are fully engaged in our recovery effort. Our continued thanks go to Winston Vickers, Deana Clifford, Linda Munson and the rest of the fox health group for their advice and work on all island fox health issues, including vaccination. Finally, now that the captive breeding program is completed (we hope!), we thank Cheri Asa, Colleen Lynch, Peter Siminski, Devra Kleiman, and the rest of the captive breeding working group for their guidance during the 10-year period of captive breeding. Foxes would not be in the wild today on at least two islands, were it not for their efforts.

As always, we are indebted to park transportation coordinator Angela Harris and dispatcher Brett West for insuring that our staff and supplies were transported to and from the islands efficiently. Contracting officer Yvonne Morales helped us procure our needed supplies, and Cindy Leon made sure we had enough funds to do so. Superintendent Russell Galipeau and natural resources chief Kate Faulkner continue to be strong supporters of fox recovery, as is Pacific West Region chief scientist Dave Graber, Peter Dratch from the NPS endangered species office, NPS Director Jonathon Jarvis, and Cathy Schwemm.

Finally, we recognize the efforts and achievements of two island fox conservation working group members who passed away recently. Linda Munson was a member of the working group from its inception in 1999. As our expert in pathology, disease, and parasites, Linda necropsied hundreds of island foxes and it is not hyperbole to say that everything we now know about island fox pathology, from the influence of canine distemper virus and unique parasites to the hallmarks of eagle predation and the prevalence of ear tumors, is due to her efforts. She is, in a word, irreplaceable. Her work will live on; her legacy is the database, papers, and book chapter resulting from her decade of island fox pathology work. Dave Garcelon summarized her success in getting folks to think more intelligently about pathology: "She brought some of us knuckle-headed biologists (sometimes kicking and screaming) to an understanding of the role that disease played in population declines and recovery, precautions necessary to hold foxes in captivity, and ideas on how to prevent future disease-related problems in fox populations."

Devra Kleiman was truly a giant in conservation biology, and became intimately engaged in the island fox recovery effort in 2003. She served as a member of the USFWS island fox Recovery Coordination Group, and her forthright East Coast manner and sense of humor enlivened both RCG and working group meetings for several years. She was a staunch supporter of captive breeding, utilizing the considerable resources of the mainland zoo community, and approaching reintroduction in a controlled, scientific manner. Though not everyone agreed with her opinions, we are the better for them. As Peter Dratch recently said, “..the Island Fox Working Group has always been an open forum to disparate opinions. While perhaps uncomfortable in any one annual meeting, in the long run, it has stretched us scientifically and widened the area of discussion. That is something Devra brought.”

Good friends, we will miss you; island foxes thrive now in the wild due to your efforts.

Introduction

The island fox, a diminutive relative of the gray fox (*Urocyon cinereoargenteus*), is endemic to the California Channel Islands. The fox exists as different subspecies on each of the 6 largest islands, a distinction upheld by morphological and genetic work (Wayne et al. 1991; Collins 1993). In 2004, the U.S. Fish and Wildlife Service listed as endangered four island fox subspecies, including the three subspecies in the Park (San Miguel Island fox [*U. littoralis littoralis*], Santa Rosa Island fox [*U. l. santarosae*], and Santa Cruz Island fox [*U. l. santacruzae*]), as well as the subspecies on Santa Catalina Island (*U. l. catalinae*) (U.S. Fish and Wildlife Service 2004). The three park subspecies had declined due to high levels of predation by golden eagles (*Aquila chrysaetos*), whereas the Santa Catalina subspecies had declined due to canine distemper virus (CDV; Timm et al. 2009).

Dramatic fox population declines on San Miguel and Santa Cruz Islands were detected during the 1990s. The island fox population on San Miguel declined from an estimated 450 adults in 1994 to 15 in 1999 (Coonan et al. 2005). The Santa Cruz population declined from as many as 2,000 adults in 1994 to 50–60 in 2000 (D. Garcelon, Institute for Wildlife Studies, unpublished data). Foxes on Santa Rosa may have numbered more than 1,500 in 1994 (Roemer et al. 1994) but declined to 15 animals by 2000 (Coonan and Rutz 2001). Prior to implementation of island fox recovery efforts, Roemer (1999) estimated time to extinction at five years for island foxes on San Miguel and 12 years for island foxes on Santa Cruz.

Predation by golden eagles was the primary mortality factor for island foxes on the northern Channel Islands, and was responsible for the massive decline of the three northern subspecies from 1994 to 2000 (Roemer et al. 2001a). Golden eagle predation was identified as cause of death for 19 of 21 island fox carcasses found on Santa Cruz Island from 1993 to 1995 (Roemer et al. 2001a). On San Miguel Island in 1998–1999, four of eight radio-collared island foxes were killed by golden eagles in a 4-month period (Coonan et al. 2005).

Until the 1990s, golden eagles never bred on the Channel Islands, and their recent colonization of the islands was due to a prey base, feral pigs (*Sus scrofa*) and mule deer (*Odocoileus hemionus*), that was not present prehistorically (Latta et al. 2005; Collins and Latta 2006). The absence of bald eagles (*Haliaeetus leucocephalus*), which bred historically on the islands and whose presence may have kept golden eagles away, may also have allowed golden eagle colonization of the islands (Roemer et al. 2001a). Island foxes evolved in the absence of significant diurnal aerial predators such as golden eagles, and therefore may have been more vulnerable to predation than other small carnivores. Moreover, on much of the northern Channel Islands, historic sheep grazing changed the predominant vegetation from shrub to non-native grasslands, which offer much less cover from aerial predators.

Upon receiving recommendations from a convened panel of experts, the Park began taking emergency recovery actions in 1999, focusing on two measures, the removal of the existing golden eagles on the islands, and captive breeding of the critically low island fox populations. In summer 1999, the Park constructed pens on San Miguel and began capture of wild island foxes for captive propagation. By January 2000, 14 island foxes had been captured and placed in the pens, leaving only 1 in the wild. Four of the captured foxes were males, and so were paired with

four females for breeding. In 2004, after five years of breeding the San Miguel captive population had increased to 50 animals, exceeding the target captive population size of 40 animals and allowing initial releases back to the wild in fall 2004. The San Miguel captive breeding and reintroduction program ended in 2007, due to high reproductive success and survival in the wild. During nine years of captive breeding, 53 pups were born in captivity, and 62 foxes released to the wild. The recovering wild population has steadily increased since releases began in 2004 (Coonan and Schwemm 2009).

A captive breeding program was initiated for Santa Rosa Island in 2000. The initial captive population on Santa Rosa was 15 animals, which proved to be the island's remaining fox population. Some females were pregnant when captured, and three litters were born in captivity in 2000. With an increase to 56 foxes in 2003, the captive population on Santa Rosa exceeded the target captive population size of 40 foxes, and initial releases began in winter 2003/2004. Annual releases continued through 2008, after which captive breeding was ceased on Santa Rosa. In nine years of captive breeding, 87 pups were born in captivity, and 93 foxes (including some of the foxes originally brought into captivity) were released to the wild.

Captive breeding was also conducted on Santa Cruz Island as a joint venture by NPS and The Nature Conservancy, which owns two-thirds of that island. The status of eagles and foxes on Santa Cruz Island was assessed at the 2001 meeting of the Island Fox Conservation Working Group, and consensus was that captive breeding was warranted for that island fox population. In February 2002, a 10-pen captive breeding facility was built on Santa Cruz Island by the National Park Service and The Nature Conservancy. This facility was stocked with 12 adult island foxes caught as known pairs or individuals from separate areas of the island. A second facility was added in 2004. No releases occurred in either 2004 or 2005, and the captive population grew to 62 animals in 2005. Releases occurred from 2006–2007, after which the program ceased due to good reproductive success and breeding in the wild.

The Park established a cooperative agreement with the Santa Cruz Predatory Bird Research Group (SCPBRG) in 1999 for the purpose of relocating golden eagles from the northern Channel Islands. Personnel from the SCPBRG began eagle surveys and removal on Santa Cruz Island, the island with the most recent sightings, in late summer 1999. Golden eagles were discovered breeding on both Santa Cruz and Santa Rosa Islands. By the end of 2006, 44 golden eagles had been removed, mostly from Santa Cruz Island, the majority by bownet trapping. Captured birds were released in northeastern California, and satellite telemetry on the first released birds indicates that none attempted to return to the islands (Latta et al. 2005).

In 2003, the Park completed a recovery strategy for island foxes on the northern Channel Islands (Coonan 2003). The recovery strategy is in the format of a U.S. Fish and Wildlife Service recovery plan, identifying threats to the species, delineating goals, objectives and recovery criteria, and presenting a schedule and cost estimates for recovery actions. Appropriate recovery goals for each of the three island fox subspecies in the northern Channel Islands were determined via demographic modeling (Roemer et al. 2001b). Population viability analysis was used to identify target population levels that would minimize the chance of extinction. Modeling was then used to set an augmentation (captive breeding and release) schedule that would achieve those targeted goals in a reasonable timeframe. The Park's island fox recovery strategy will be

superseded by an official island fox recovery plan currently being developed under the direction and authority of the U.S. Fish and Wildlife Service.

The decade of recovery actions has resulted in notable progress toward island fox recovery (Coonan and Schwemm 2009). Island fox populations on the northern Channel Islands have increased from 15 apiece on San Miguel and Santa Rosa and <80 on Santa Cruz to populations that number in the hundreds on the former islands and close to 1,000 on Santa Cruz. This is due to the success of captive breeding and reintroduction, and the success of golden eagle removal. Reintroduced foxes and their progeny reproduced readily in the wild, and survival increased to over 90% on all three islands as golden eagle presence and predation decreased. Rapid population growth has moved each population toward levels that indicate recovery and likelihood of persistence over time (Bakker and Doak 2009). The large-scale ecosystem restoration actions of feral pig removal and bald eagle reintroduction have nudged the islands' ecosystem toward a point which favors fox persistence and discourages future golden eagle colonization of the islands. The court-ordered removal of non-native mule deer (*Odocoileus hemionus*) and elk (*Cervus elephus*) from Santa Rosa Island in 2011 will remove the last of the non-native prey base from the northern Channel Islands.

Island fox decline and recovery has caused changes in the islands' ecosystem structure and function, some of which can be tracked via both annual island fox population monitoring and the park's long-term ecological monitoring program (see Ch. 14, The Ecological Role of Island Foxes, in Coonan et al. 2010). Recorded changes due to the absence – and reappearance – of island foxes include those in deer mouse (*Peromyscus maniculatus*) and landbird populations. In addition, island spotted skunks (*Spilogale gracilis amphiala*) are the only other terrestrial carnivores on the Channel Islands, and inhabit Santa Cruz and Santa Rosa Islands. Island spotted skunks compete with island foxes, and increased when foxes declined on both islands in the mid-1990s (Crooks and Van Vuren 2002). As foxes recover, island spotted skunks may decrease, and this interaction may be tracked via island fox population monitoring.

Integrated Island Fox Recovery Team

From 1999–2003, the NPS convened a group of experts annually to help evaluate the status of island foxes on Park lands, and to make findings regarding appropriate recovery actions. The Island Fox Conservation Working Group, as it was called, comprised a loose affiliation of public agency representatives, landowners, conservancies, zoological institutions, non-profits, and academics concerned about conservation efforts for the island fox.

The working group served as a forum for information exchange and evaluation of recovery efforts, dividing into subject matter groups to tackle most issues. The group annually reported the status of island foxes on all islands and listed findings in regard to threats to the species and appropriate mitigation actions (see Appendix A in Coonan et al. 2004).

After listing four island fox subspecies as endangered in 2004, the U.S. Fish and Wildlife Service established an island fox recovery team that retained the characteristics of the Island Fox Conservation Working Group. Although many recovery teams comprise a small number of individual experts, the Service established an integrated island fox recovery team comprising all 70+ individuals from the former working group. The individuals served as members of specific

technical expertise groups, from which individuals were chosen to work on task forces in response to requests from land management agencies (NPS, TNC, Catalina Island Conservancy) regarding management and recovery of island foxes. The task requests were allocated to task groups by the island fox recovery coordination group, which also received the resulting analyses from the task groups and passed on recommendations to the land management agencies, via the Service.

The integrated island fox recovery group first met in June 2004 to establish technical expertise groups and task forces, and begin addressing the task requests formulated by the land management agencies. The team met again in 2005 and 2006 to exchange information on fox conservation and research, review completed work on task requests and recommendations to land managers, continue work on task requests, and provide input to FWS on development of the draft island fox recovery plan (which had been tasked to the recovery coordination group). The 2007 island fox meeting marked a return to a format similar to the island fox conservation working group meetings. This included exchange of information and small workgroups addressing issues raised by the land management agencies, but not in the formal task analysis request process established by FWS.

A smaller group, the Recovery Coordination Group, was tasked by the U.S. Fish and Wildlife Service with developing an island fox recovery plan, and the annual island fox meetings in 2005 and 2006 were used to develop recovery actions, criteria and strategies for inclusion in the plan. As of 2010 the plan had not been released to the public, but the process of developing island fox recovery criteria based on demographic modeling had been published (Bakker and Doak 2009). Information on the integrated island fox recovery team, and on the draft island fox recovery plan, is available from the Ventura Field Office of the U.S Fish and Wildlife Service.

This report covers island fox recovery actions conducted by park staff in calendar year 2009, but we also include data from early 2010. The recovery actions, which included island fox population and mortality monitoring, were conducted under U.S. Fish and Wildlife Service Recovery Permit TE86267-0, which has separate reporting requirements (Coonan 2010). Island foxes have been monitored since reintroductions began in 2003. Prior to the catastrophic decline of the 1990s, island fox population monitoring was conducted on San Miguel Island as part of the park's longterm ecological monitoring program (Coonan et al. 1998).

In 2009 we captured and monitored island fox populations on San Miguel and Santa Rosa Island via small trapping grids and transects. Our monitoring objectives were to:

- Assess the physical condition of individual foxes.
- Vaccinate foxes against canine distemper virus and rabies.
- Estimate fox population density, age structure, sex ratio, reproductive success and island-wide population size.
- Estimate annual survival and cause-specific mortality via radiotelemetry.
- Track population trend in the island fox's primary competitor on Santa Rosa island, the island spotted skunk, by marking skunks trapped during grid monitoring and estimating population size.

Methods

Field Methods

On San Miguel, grid trapping for density estimation was conducted in August and September, and transect trapping to complete management of radio collars and vaccination was conducted from October through December (pups are not large enough to radio-collar until the fall). On Santa Rosa, grid trapping was conducted July–September, and transect trapping from October through December. Box traps (23 by 23 by 66 cm, Tomahawk Live Trap Co., Tomahawk, WI) were baited with dry and wet cat food and a fruit scent (Knob Mountain Raw Fur Co., Berwick, PA). Captured foxes were protected from the elements by careful placement of traps, and by a shade cloth cover on each trap. A polyethylene tube chew bar was wired inside each trap to reduce incidence of tooth damage. Traps were checked once, in the morning, during every 24-hr period. Specific trap locations were determined by the sampling design for estimating population density, as described below.

Upon first capture, animals were weighed in the trap, and then removed and handled without anesthesia for a complete work-up. Data collected included sex, reproductive status, age class, and general physical condition (e.g., condition of coat, presence of ectoparasites, injuries). Captured foxes were marked with passive integrated transponder (PIT) tags (Biomark, Boise, ID) inserted subcutaneously between and just anterior to the scapulae. Single-use sterile PIT tag applicators were used in order to minimize transfer of pathogens. Prior to insertion of the PIT tag, the insertion site was cleaned and disinfected with alcohol, and antibacterial ointment was applied to the needle.

For foxes which had never been captured before, a blood sample was collected from the femoral or jugular vein of captured foxes, separated into its component fractions by centrifugation, and stored for later genetic and serologic analyses. Up to 10 ml of blood was collected from adult (>1.25 kg) foxes, and up to 5 ml from pups. Staff taking blood samples have had previous experience in drawing blood, and are supervised by permitted individuals while collecting blood from island foxes. A portion of the serum from each was set aside for archiving at the Institute for Wildlife Studies. Additionally, a portion of the blood samples collected were to be sent to the American Museum of Natural History, under a recent national agreement between that institution and the NPS for archiving biological specimens of endangered species.

Mortality-sensing radio-telemetry collars were placed on a subset of foxes captured in order to assess mortality rates and factors. Because a sample of 40+ radio collars is considered adequate to assess mortality rate in island foxes (Bakker and Doak 2009), and we expect about 10% annual mortality, our objective was to have over 50 foxes radio-collared on each island by the end of trapping season. We wanted the sample of radio-collared foxes to be evenly distributed across each island, and divided equally among males and females. Our age structure goals were to collar approximately 10 pups and 10 yearlings, with the remaining collars spread among older age classes. Radio collars (MI-2M, Holohil Systems Ltd, Ontario, Canada) weighed 42 g, which was approximately 2% of a typical island fox' weight (2.0 kg). Under our permit, radiocollars can weigh no more than 4% of a fox' weight. Radiocollars transmitted in the 167–168 MHz

range and were equipped with mortality sensors, which doubled the pulse rate when the collar was stationary for 6 hr.

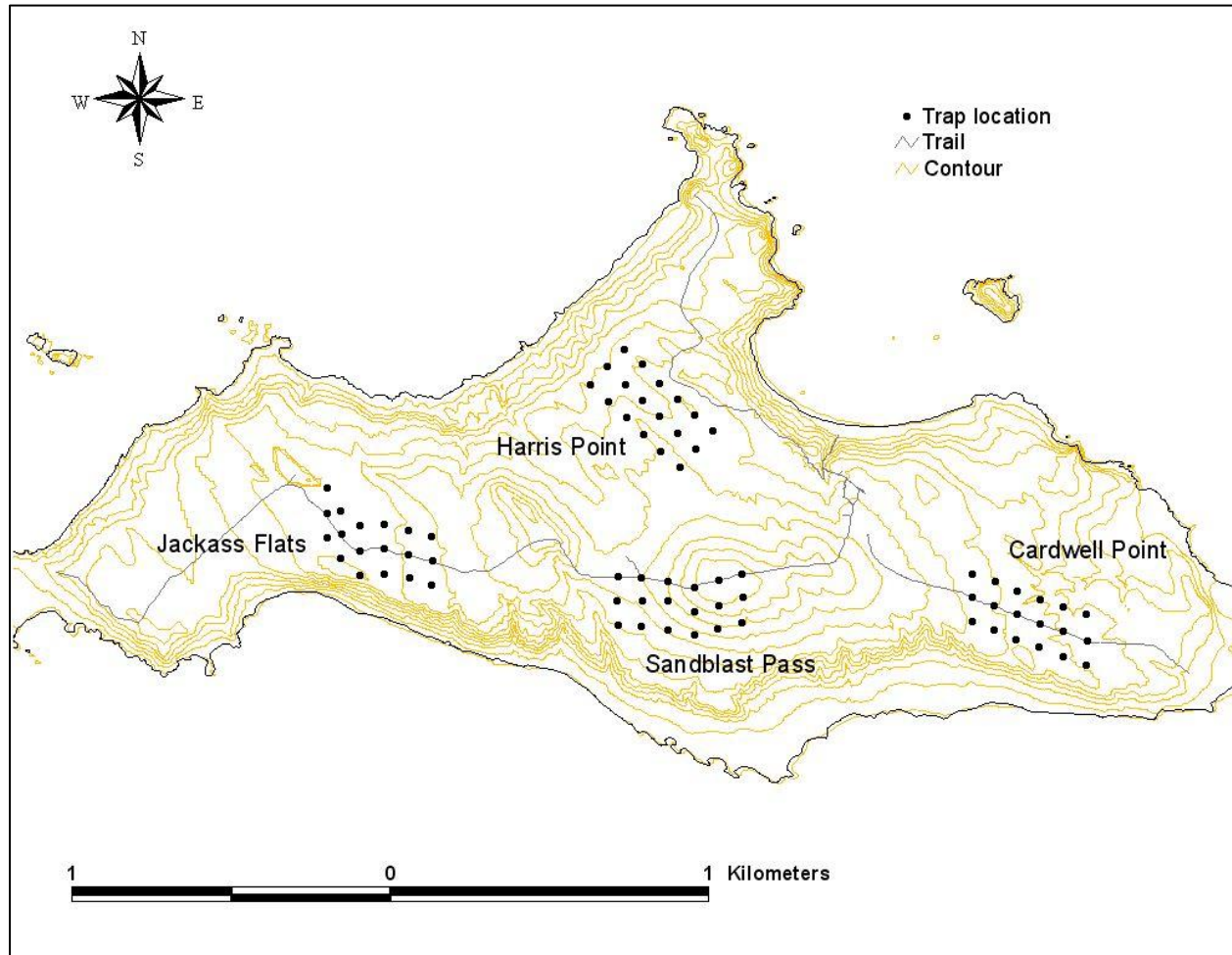


Figure 2. Location of four fox trapping grids, San Miguel Island.

Density Estimation

To estimate density and island-wide population size, four small (3 x 6) grids were trapped on San Miguel. Three grids were randomly distributed along the primary east-west cross-island trail and a fourth was placed north of the central dunes and south of Hurricane Deck/Harris Point, in the only area without cultural resources (Figure 2). For each grid, one line of traps was dispersed along the trail at 250m intervals, with another line of traps directly north and south of each trap-point on the trail. The grids were designed to be relatively easy to set up and trap, so that a two-person crew could trap one grid per week while still performing other duties (captive fox care, monitoring radio-collared foxes). The grids were run for five nights.

Previous population monitoring on Santa Rosa utilized line transects, from which it is difficult, if not impossible, to estimate density and thus island-wide population size. There are less recaptures along transects, which are linear trap arrays, and so transects offer less information

about distance moved and effective trap area of home range size. Therefore in 2009 we shifted to grid monitoring, and established 18 “ladder” grids (Figure 3), each comprising a 2 x 6 trap array, as recommended by Rubin et al. (2007).

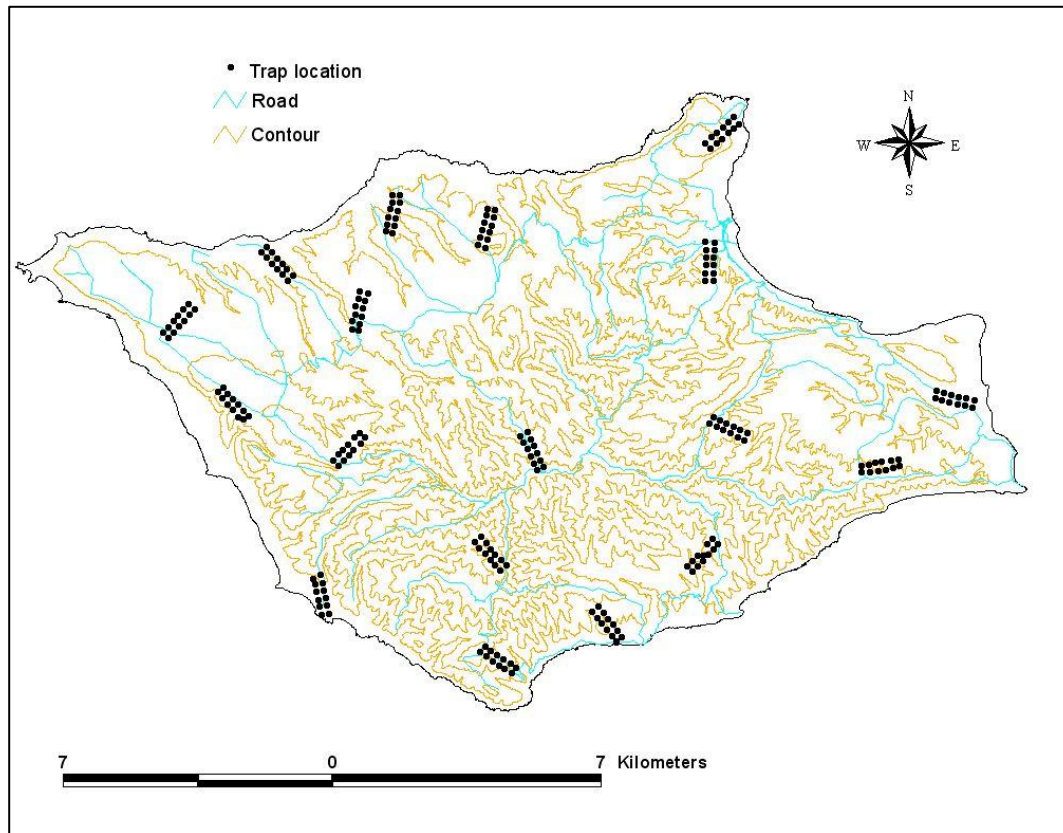


Figure 3. Location of 18 randomly placed “ladder” grids, Santa Rosa Island.

Capture-recapture data from each grid was analyzed via program Density (Efford et al. 2004), which models captures as a joint function of density (D), detection (g_0), and spatial scale or movement (σ) parameters. We used the maximum likelihood estimator and considered each grid to be a separate trapping session. Average density from the grids was multiplied by island size to estimate island-wide fox population size. Both the standard error for the average density and the standard error for the island-wide population estimate were calculated via the delta method (Cooch and White 2006).

During trapping on Santa Rosa, we also marked island spotted skunks (*Spilogale gracilis amphiala*) with PIT tags, and so were able to estimate skunk density and island-wide population size with program Density.

Survival and Cause-specific Mortality Rates

Collared foxes were monitored weekly to determine their general location and signal type (normal or mortality). If a mortality signal was detected, the dead fox was located and recovered. Data collected at the site prior to removing the carcass included: 1) any information that might indicate cause of mortality, 2) the position of the carcass with respect to its surroundings, including digital photographs, and 3) the general condition of the animal (e.g., eviscerated, intact, damage by insect scavengers, etc.). The location of the carcass was recorded via GPS, and a general description of the habitat was recorded.

Carcasses were tagged with pertinent identification, date, and location information. If a carcass could be brought to the mainland within 48 hours of being located, they were refrigerated; otherwise they were frozen and then shipped by overnight carrier to the UC Davis, Wild Carnivore Pathology Laboratory (Dr. Linda Munson) for necropsy. Because freezing of tissues increases autolysis, and therefore decreases data that can be extracted from histological examinations, it is advantageous to have the animal necropsied as soon as possible after death and to avoid freezing if possible. If disease was suspected in the death of the animal, tissues were prepared for histological analysis by UC Davis veterinary staff.

Annual survival of radio-collared foxes was estimated with the non-parametric Kaplan-Meier procedure with staggered entry of foxes as they were released to the wild, and of wild-born foxes as they were radio-collared (Pollock et al. 1989). We calculated an 80% confidence interval about the annual survival rate, as the 95% confidence interval is too conservative (University of California, Davis, V. Bakker, and University of California, Santa Cruz, D. Doak, personal communication).

For San Miguel, we used the island-wide population estimate and annual mortality (1–annual survival) to determine if the recovering fox population met draft demographic recovery criteria being developed by the U.S Fish and Wildlife Service for its island fox recovery plan. Recent demographic modeling incorporated life-history characteristics of the well-studied island fox with environmental drivers and uncertainty to develop extinction probabilities for combinations of population size and annual mortality (Bakker et al. 2009). We plotted three-year averages of adult population size and adult annual mortality to determine if those values resulted in acceptable extinction risk (5% over 50 years; see Bakker and Doak 2009).

Results and Discussion

San Miguel Island

Captive Breeding

The San Miguel captive breeding program ceased in fall 2007 after the final 14 foxes were released from captivity. One unreleasable island fox (PIT tag 7534A) remained in captivity on that island until her death by euthanasia on 18 April 2009. Her health had declined to the point where euthanasia was the only option. Examination by Dr. Karl Hill of the Santa Barbara Zoo on 18 April revealed fractured vertebra and permanent paralysis, perhaps due to spondylosis or cancer. She was a 16–18 year old brought into captivity in 1999 as a potential founder, though she failed to breed in captivity. She was first caught on the original San Miguel monitoring grids in 1994, when she was identified as an age class 2 (2–3 year old) animal. When she was trapped the following year she had signs of having lactated, so she likely bred in the wild.

Mortality Monitoring

Throughout 2009 we maintained a sample of 35–60 radio-collared foxes on San Miguel, and by the end of the year there were 60 radio-collared foxes being monitored (Table 1). Collared foxes included those previously released from captivity and wild-born foxes. Annual Kaplan-Meier survival for San Miguel island foxes in 2009 was 93.0% (80% CI = 89–97%). Annual survival has remained above 80% since foxes were first released on San Miguel in 2004 (Figure 4).

Table 1. Number of radio-collared foxes, by age and sex, on San Miguel and Santa Rosa Islands at the end of 2009.

Age Class	San Miguel			Santa Rosa		
	Males	Females	Total	Males	Females	Total
0	5	0	5	3	4	7
1	16	10	26	9	13	19
2	7	11	18	7	4	11
3	2	1	3	2	3	5
4	5	3	8	2	3	5
Total	35	25	60	23	27	50

Four radio-collared foxes died in 2009, none from eagle predation (Table 2). One (M221) may have died due to predation from a small raptor. That carcass, which was intact (not eviscerated or de-gloved) had wounds consistent with small raptor predation: perforation of the abdominal and thoracic cavities which resulted in a hemothorax (accumulation of blood in the pleural cavity) and collapsed lung, with accompanying infection and hemorrhage (University of California, Davis, L. Munson, personal communication). The punctures were too small and too narrowly spaced to be due to golden eagle predation. Two cases of “incomplete” predation, possibly attributed to eagles, occurred on Santa Rosa, one in January and one in March (see section on Santa Rosa Island, p. 18).

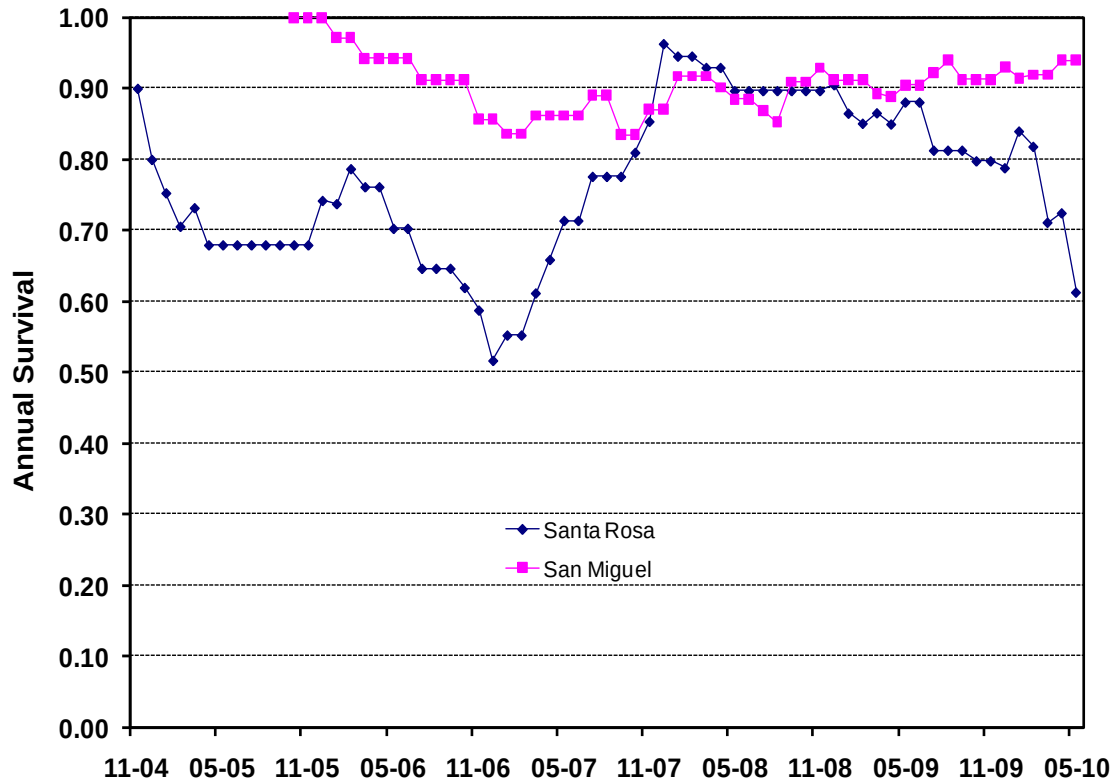


Figure 4. Rolling annual Kaplan-Meier survival for island foxes, San Miguel and Santa Rosa Islands.

Table 2. Island fox mortalities, San Miguel Island, 2009.

PIT Tag	ID	Sex	Born	Age	Died	Mortality Cause
93901	M221	M	Captive	5	3/18/2009	Predation, incomplete, by small raptor.
11929	F327	F	Captive	9	4/1/2009	unknown, not predation
71071	F334	F	Wild ¹	10	9/25/2009	unknown
84E33	M206	M	Captive	6	12/1/2009	Asphyxiation; cave-in

¹Founder released to wild in 2007

All four collared foxes that died had been released from the wild, and one (F334) was a founder of the captive population released in 2007. In captivity she produced seven pups in four litters. Certainly one of the more unusual mortalities recorded was that of M206, who apparently died of asphyxiation when his den collapsed (Figure 5). The den was located in a sandy slope near the beach at Crook Point, and its collapse may have been facilitated by a period of substantial rains in mid-December 2009 (the mortality date is approximate; M206 was last heard in normal mode on 14 November 2009, and was heard in mortality mode on 27 December 2009).



Figure 5. Collapsed den and mortality site for M206, San Miguel Island.

Population Size, Density, and Reproductive Success

Grid trapping in summer/fall 2009 yielded the following measures of population health:

- Density (foxes/km²) on 4 grids
- Island-wide population estimate, extrapolated from average density
- Reproductive effort

The four small grids were trapped from late July through late September and a total of 79 individuals (21 pups and 58 adults) were trapped. Adult density on the four grids ranged from 5.4–7.3 foxes/km², with an average density of 6.64 foxes/km² (Table 3). The coefficient of variation for the island-wide density estimate was 0.15. A CV < 0.20 is desirable for management purposes (Landcare Research, M. Efford, personal communication). Multiplying the average density by the area of the island (38.1 km²) yielded a population estimate of 256 adult foxes, with 80% CI = 208–305 adult foxes. When pups were included in density estimates, the island-wide population estimate was 318 foxes, with 80% CI = 267–369.

Table 3. Adult density estimates for small grids, San Miguel Island, 2009.

Grid¹	Date Trapped	Individ.	Capture Prob.	Density (foxes/km²)	SE	CV²
CARD	8/06–8/10	12	0.388	5.36	1.726	0.32
SAND	8/20–8/24	16	0.322	7.04	2.004	0.29
JACK	9/02–9/06	16	0.400	7.33	2.093	0.29
CHAR	9/17–9/21	15	0.253	6.82	2.001	0.29
average				6.64	0.980	0.15

¹CHAR = Harris Point, CARD = Cardwell Point, SAND = Sandblast Pass, JACK = Jackass Flats

²Coefficient of Variation = standard deviation/mean

Since reintroduction began in 2004, the wild island fox population has increased (Figure 6) due to annual reintroduction (2004–2007) and to reproduction in the wild. It is unclear why the estimated population size did not apparently increase from 2007 to 2008, because the number of foxes caught on each grid increased consistently over the three-year period (Figure 7). The annual rate of increase (λ , or lambda) was >2.0 in 2006 and 2007, and declined to <1.0 in 2008, and was 1.39 in 2009 (Table 4). Average λ was 1.68. Values of $\lambda > 1.0$ indicate an increasing population.

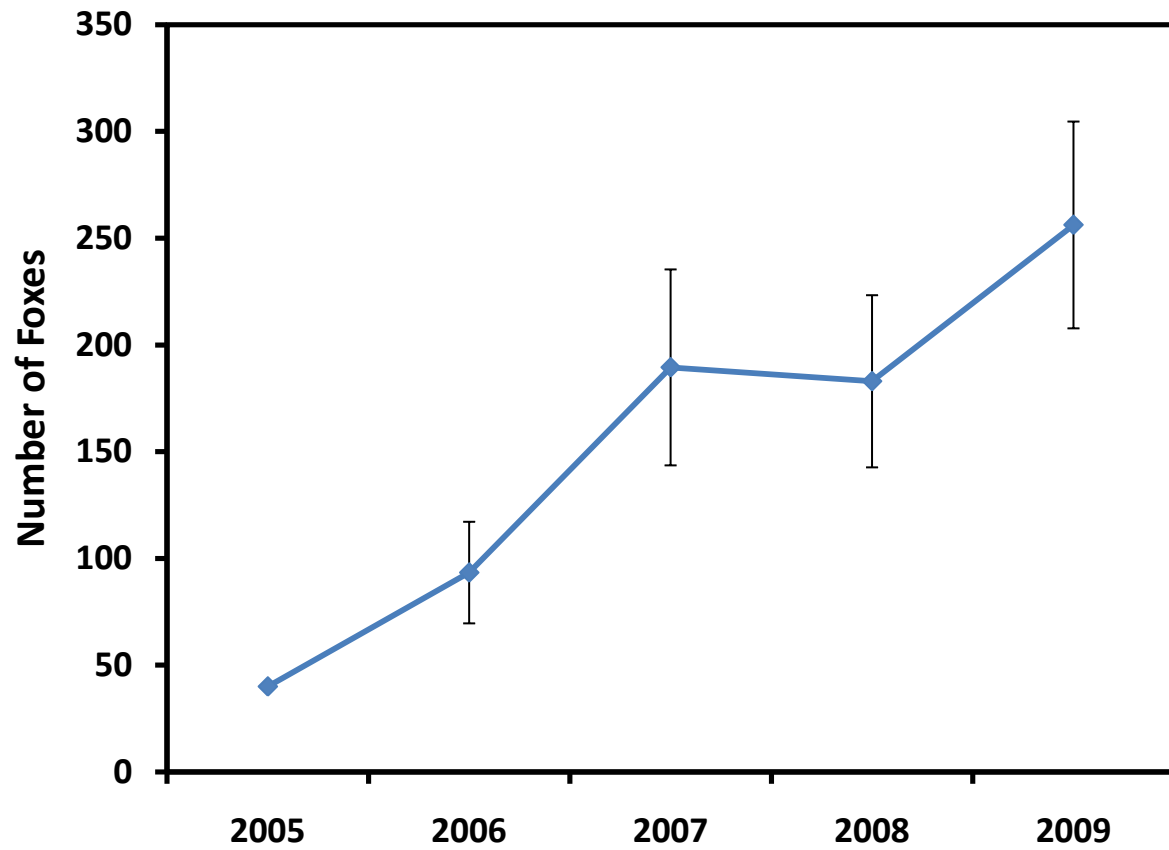


Figure 5. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from minimum number known to be alive (MNKA) for 2005 and grid-based density estimation for 2006–2009. MNKA is not an estimate, so there is no confidence interval.

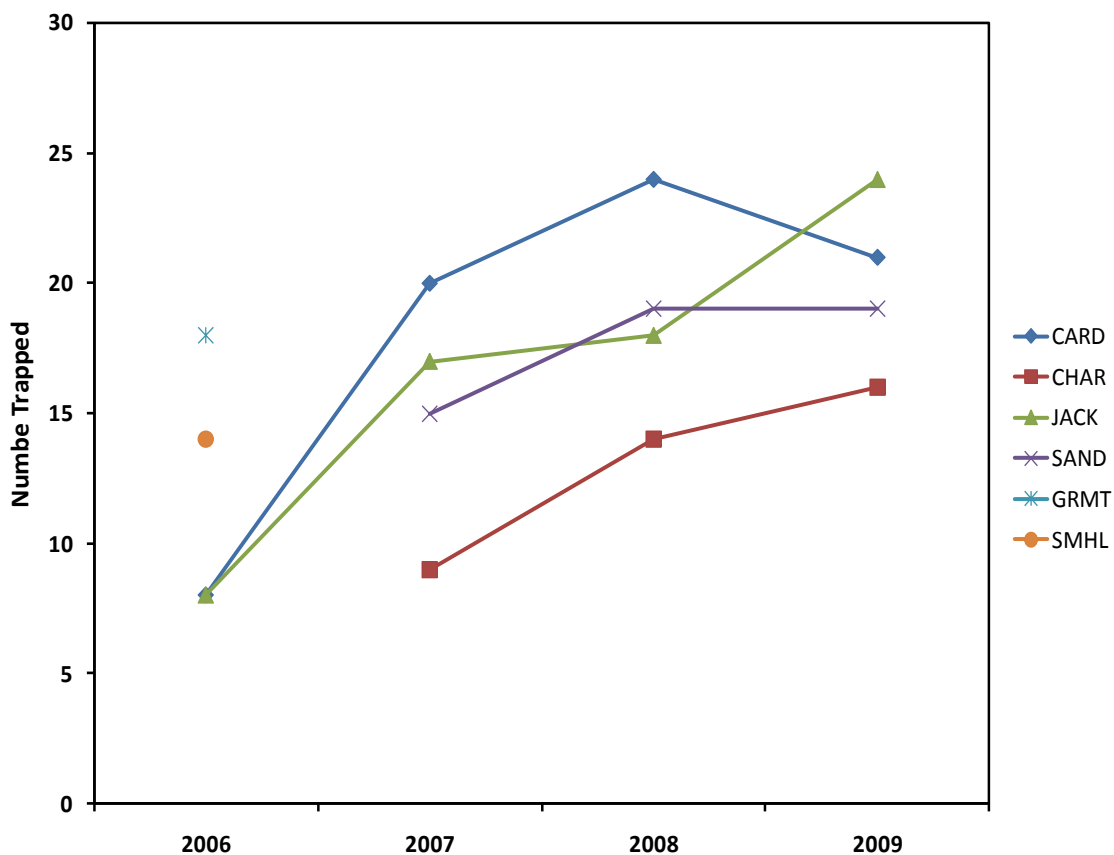


Figure 6. Number of foxes (adults and pups) caught on each grid, San Miguel Island, 2006–2009. Green Mountain (GRMT) and San Miguel Hill (SMHL) were surveyed only in 2006; monitoring at Harris Point (CHAR) and Sandblast Pass (SAND) began in 2007.

Table 4. Island-wide adult population estimate from grid density estimates (2006–2009) and from transect trapping (2005), San Miguel Island.

Year	N	SE	Variance	80% CI	lambda
2005	40*				
2006	93	18.58	345.28	70–117	2.33
2007	190	35.85	1285.50	144–235	2.04
2008	183	31.51	992.59	143–223	0.96
2009	256	37.80	1432.05	208–305	1.39

*Minimum number known to be alive from trapping and radiotelemetry

A tally of captured foxes by sex and age indicated a bias toward males in pups, and overall. The adult population was biased toward males, as were the number of pups born in the wild (Table 5). Four of the 29 wild-born pups caught on the grids and on transects were subsequently radio-collared. We measured reproductive success as the ratio of pups (21) to number of adult females (25) captured on the grids. The estimated reproductive success of 0.84 pups/female was

relatively low, compared to values from other years (including data from 1993–1999, encompassing the population decline). Regression of reproductive effort on adult population size showed reproductive effort declining as population increases, a density-dependent effect (Figure 8). The 2009 value fell below the regression line, suggesting that relatively low reproduction in 2009 may be due to other factors, such as drought.

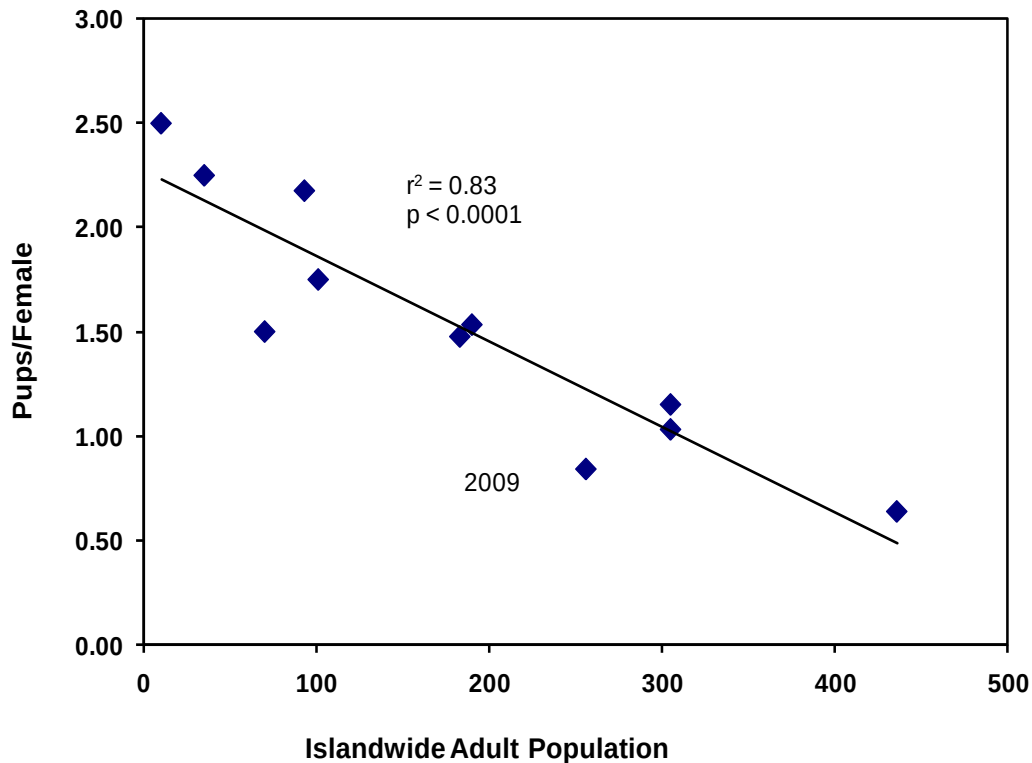


Figure 8. Reproductive effort (pups/female) and island-wide adult population estimate, San Miguel Island, 1993–2009.

Table 5. Number of foxes captured, by age and sex on 4 grids on San Miguel, 2009.

	Male	Female	Total
Pups	17	4	21
Adults	33	25	58
Total	50	29	79

To determine whether the San Miguel population was approaching biological recovery, we plotted three-year averages of adult population size and adult mortality using a spreadsheet tool developed by Vicki Bakker of the University of Arizona. The tool plots current values against isoclines representing various levels of extinction risk for island foxes on each island (Bakker and Doak 2009). These models are being incorporated as biological recovery criteria in the draft

island fox recovery plan currently being developed by U.S. Fish and Wildlife Service. The plots of three-year averages for 2008 and 2009 (Figure 9) show that the 80% confidence limits for both mortality and population size fell below the 5% isoclines, which is the acceptable level of risk identified in the draft recovery plan. The San Miguel population reached biological recovery in 2008, and the values for 2009 indicated even greater probability of avoiding extinction. However, the plan contains other requirements for de-listing: these levels must be reached for five continuous years, and there must be monitoring and actions plans in place for detecting and mitigating future episodes of predation and disease. Nonetheless, the San Miguel population reached a measure of biological recovery five years after being listed, and 10 years after the population had declined to 15 individuals, at which point recovery actions began.

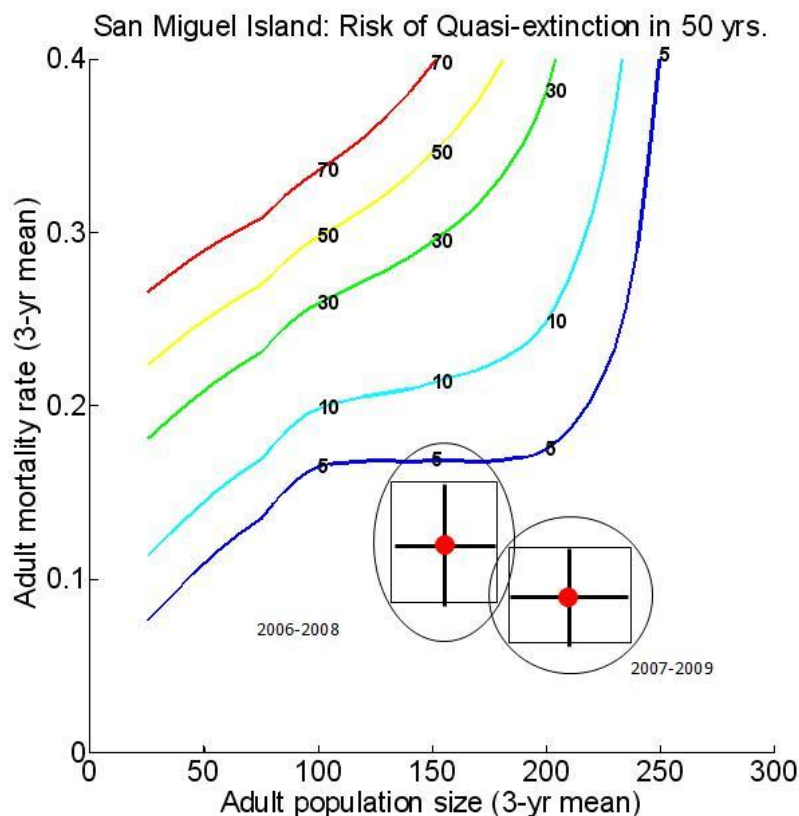


Figure 9. Extinction risk for San Miguel Island foxes under 2006–2008 and 2007–2009 averages for adult mortality and population size. Ellipses are 80% confidence intervals for combination of mortality rate and population size.

Vaccination of Wild Foxes

After the grids were trapped, transect trapping was conducted to mange radio-collars and to vaccinate wild foxes. An additional 39 foxes were trapped during transect trapping. Of the 118 foxes trapped during both grid and transect monitoring in summer/fall 2009, 104 were vaccinated against rabies and 110 were vaccinated against distemper. On San Miguel we have been following the guidelines for small populations (< 100), that all foxes should be vaccinated for both CDV and rabies. Although the adult population is well above 100 foxes, we will continue to

use those guidelines. The alternative is the “vaccinated core” strategy, in which 80–100 foxes in a certain area of the island are vaccinated against CDV (see guidelines for vaccination in Fox Health Working Group report, Schwemm 2008). This allows a portion of the population to be conferred immunity via the vaccine, and a portion to be conferred immunity via the naturally occurring strain of CDV (or other morbillivirus) that is present in all island fox populations (Clifford et al. 2006). However, in a trapping season on San Miguel we are unlikely to trap and handle 80–100 foxes in one portion of the island (in 2009, we handled 117 island-wide). Additionally, 10–20 collared juvenile foxes should remain unvaccinated, to act as sentinel animals for detection of pathogen outbreaks. During the 2010 trapping season we will establish a sample of unvaccinated, collared sentinel animals.

In 2009, blood samples were collected from 29 San Miguel foxes which had not been caught previously.

Future Plans

Results from monitoring in 2009 indicate that the wild population on San Miguel is still in a phase of expansion. Survival is high, reproductive success is relatively high, and the average rate of increase, or lambda, from 2005 to 2009 was 1.68. Although captive breeding ceased on San Miguel Island in 2007, other recovery actions will continue. A portion of the wild population (40–60 foxes) will be radio-collared and regularly monitored for mortality rate and causes. Trapping will be conducted in summer/fall 2010 on the four small grids to estimate population size and reproductive effort. We will attempt to vaccinate all of the foxes trapped in 2010 against canine distemper virus and rabies. This will result in a vaccinated population of at least 100 foxes. Ten to 20 juvenile (1-year old) foxes will be radio-collared but not vaccinated, to serve as a “sentinel” population to detect outbreaks of other types of pathogens.

Santa Rosa Island

Captive Breeding and Reintroduction

Two island foxes remained in captivity on Santa Rosa Island in the beginning of 2009, and one of those foxes subsequently died in captivity. Male B067E (“Hef”) died on 13 March 2009. Because of his age and tendency to be injured by his pups and mate, he was one of two foxes considered unreleasable and thus not included in the large releases that closed the captive breeding program in fall 2008. Necropsy revealed that his somewhat unexpected death (he had not been in decline) was due to exsanguinations (extensive hemorrhage) in the peritoneal cavity, the cause possibly being rupture of a blood vessel (University of California, Davis, L. Munson, personal communication). In captivity he sired 11 pups, one female pup in 2000 with female 1612C, and ten male pups in five litters with female 47304.

The remaining fox in captivity was male 8024B, born in captivity in 2006 and diagnosed that year with a grade 5 heart murmur. The latter condition, considered to be life-threatening, initially made him unreleasable, and so he was not released in 2008. However, his condition never worsened, and it became obvious that he would live longer than the six months to one year he was predicted to live when initially diagnosed with the heart murmur. Because he was genetically valuable, we decided to release him in 2009 in hopes that he would have at least one litter in the wild. On 14 November 8024B was examined by Dr. Winston Vickers and Dr. Kopit, who conducted a cardiac ultrasound to see if there had been any changes from his last cardiac ultrasound conducted almost two years previously. Overall the exam did not turn up anything to prevent his release. The fox was kept in the foxpital overnight to recover from his exam and released the next day, 15 November, at dusk in Quemada Canyon as collar ID M78.

Mortality Monitoring

Throughout 2009 we maintained a sample of 46–65 radio-collared foxes on Santa Rosa, and by the end of 2009 there were 49 radio-collared foxes on the island. Collared foxes included those released from captivity and some wild-born foxes. Annual Kaplan-Meier survival for Santa Rosa Island foxes in 2009 was 84.0% (80% CI = 78–90%). An annual survival rate of 80% is required for a stable or increasing fox population (Roemer et al 2001). In 2009, annual survival on Santa Rosa, which had previously been lower than that on San Miguel, remained near or above 80% for the second consecutive year (Figure 4). However, by March 2010 annual survival on Santa Rosa had declined to 61% due to eagle predation and other unknown mortality factors.

Nine radio-collared foxes died in 2009, from a variety of causes (Figure 10, Table 6). Although final necropsy results are not available for any of the mortalities, preliminary results and field observations of carcasses allowed determination of likely cause. Five of the nine mortalities, as well as that of an uncollared fox, were positively or possibly due to predation. Two mortalities in early 2009 (M65 and F161) and one of an uncollared fox in November were due to incomplete predation, in which the carcass was intact and not consumed. Preliminary necropsy results indicate that both M65 and F161 had puncture wounds consistent with predation (L. Munson, University of California, unpublished data): M65 died from infection of the thorax (pleuritis) and peritoneal cavity (peritonitis) that developed from the puncture wounds, and F161 died from punctures in the thorax (pneumothorax and collapsed lung).

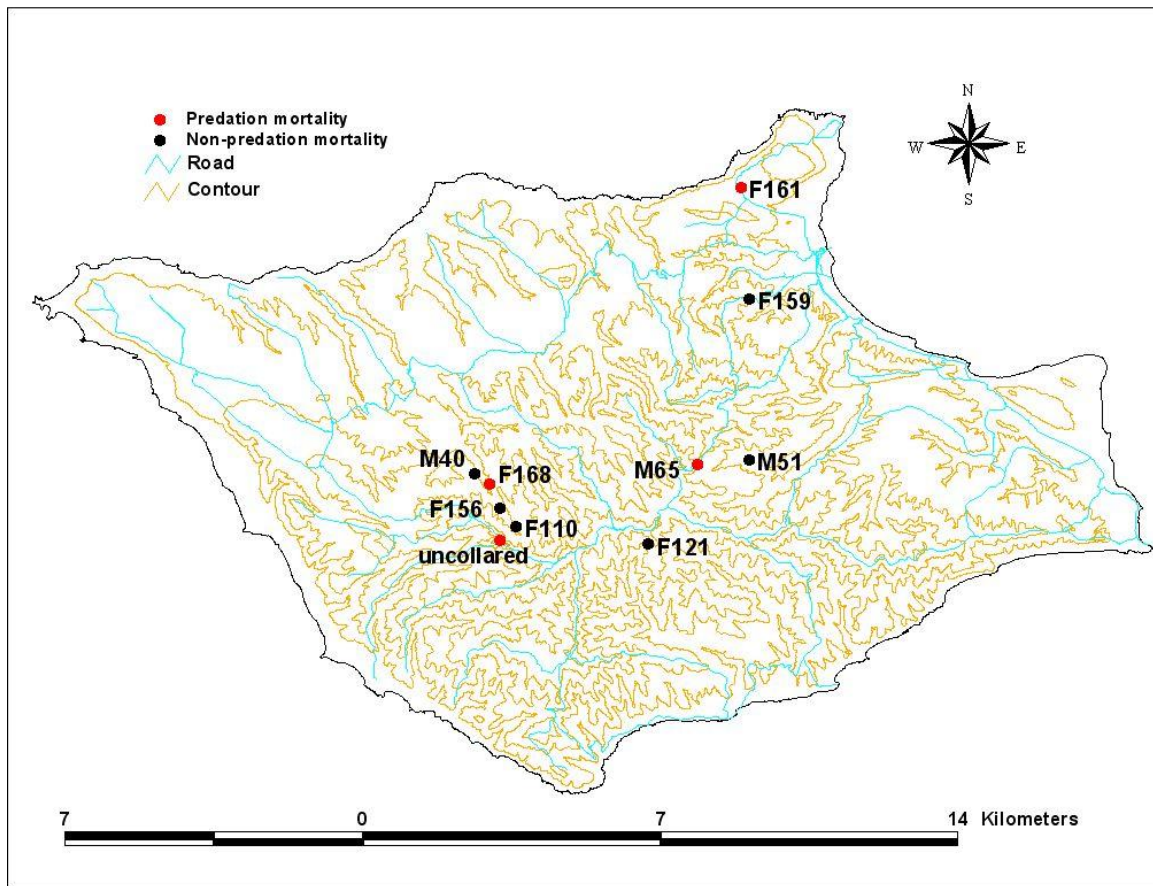


Figure 10. Location of radio-collared island fox mortalities, Santa Rosa Island, 2009.

One fox (M159) became entrapped in a deep plastic pipe near the underground water storage tank above the housing area. Another fox (F121) was strangled when its radio collar became entangled on the branch of a shrub.

In February, March and April 2010, 11 radio-collared foxes died from eagle predation, and two died from unknown causes (the carcasses were intact, ruling out predation) (Table 5, Figure 10). Additionally, one radio-collared fox and one uncollared fox died from predation in November 2009. The latter fox, which had neither a radio-collar nor a PIT tag, was found by island hunt personnel and retrieved by fox program staff. Feathers found at one mortality site (that of M02, Figure 11), were identified as golden eagle feathers (U.S. Fish and Wildlife Service,, P. Trail, personal communication; Figure 12). Similar feathers were found at the M59 mortality site in April. On 5 March 2010 a golden eagle was observed in the Lopez Peak area, near the recent predation mortalities, by Institute for Wildlife Studies staff surveying for bald eagles on Santa Rosa Island. Another sighting was recorded by IWS staff on 7 March, and an additional sighting was recorded in the Burma Oaks area on 17 April during a survey for loggerhead shrikes (*Lanius ludovicianus*).

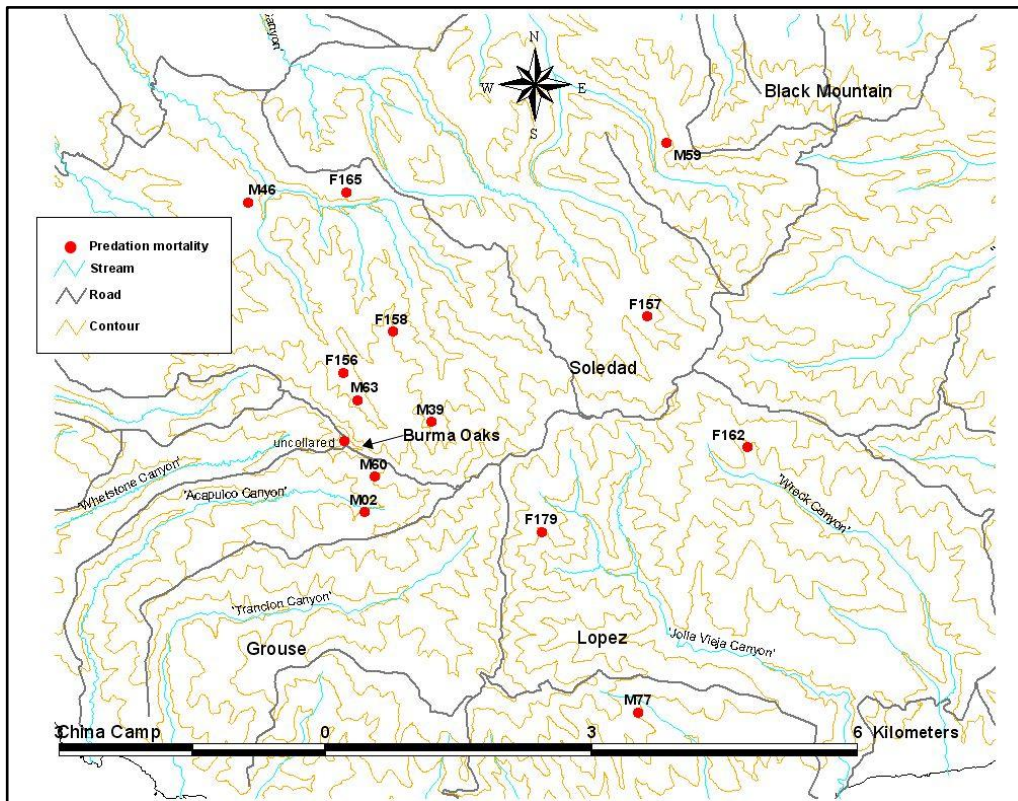


Figure 11. Predation-caused island fox mortalities, Santa Rosa Island, November 2009–April 2010.

Table 6. Island fox mortalities, Santa Rosa Island, 2009–2010.

Date	PIT Tag	Other	Sex	Born	Age	Mortality Cause and Findings
1/27/2009	C4F63	M65	M	Captive	6	Predation, incomplete: pleuritis and peritonitis from puncture wounds
3/16/2009	90B2B	F161	F	Captive	3	Predation, incomplete: punctures in thorax, collapsed lung
6/4/2009	A7954	F110	F	Captive	6	Predation
6/18/2009	C4A1F	F159	F	Captive	3	Entrapped in pipe
6/24/2009	D590E	F168	F	Captive	4	Unknown: puncture wounds
7/30/2009	13737	F121	F	Wild	4	Strangled, collar on branch
9/6/2009	47E09	M40	M	Captive	6	Unknown: not predation
11/3/2009	None	uncollared	M	Wild	1	Incomplete predation
11/13/2009	8422B	M51	M	Wild	3	Unknown: not predation
11/15/2009	0714F	F156	F	Captive	1	Predation
2/1/2010	65F0A	F158	F	Captive	3	Predation
2/1/2010	75125	M02	M	Captive	9	Predation
2/10/2010	25D54	F171	F	Captive	8	Unknown: not predation
2/14/2010	84542	F179	F	Wild	1	Predation
2/20/2010	E1D7D	M46	M	Wild	4	Predation
2/21/2010	3784A	M39	M	Captive	3	Predation
3/1/2010	D003E	F157	F	Captive	2	Predation
4/2/1010	13B68	M59	M	Captive	3	Predation
4/8/2010	E1207	F165	F	Captive	2	Predation
4/11/2010	64A43	M60	M	Captive	5	Predation
4/11/2010	7235F	M63	M	Captive	6	Predation
4/11/2010	E6D1E	F124	F	Captive	9	Unknown: not predation
4/19/2010	14454	F162	F	Captive	3	Predation

Although there are currently no predation or eagle “triggers” which prompt a management response, NPS decided to initiate a capture attempt, due to the number of predation mortalities, the decline in annual survival, the presence of golden eagle feathers and recent credible sightings of golden eagles. In March 2010, NPS contracted with Native Range Inc. for a helicopter net-gunning golden eagle capture effort. During the survey flight on 12 March, no eagles were observed. A ground-based survey utilizing skilled spotters was conducted April 26–27, and a second helicopter survey was conducted on 27 April. Neither recorded golden eagles. Golden eagle use of Santa Rosa may be variable, when birds are not attempting to nest (the sighting on 17 April was of a sub-adult). Periods of high winds after mortalities and prior to surveys may also have resulted in golden eagles temporarily leaving the island for more sheltered habitat.



Figure 12. Golden eagle feathers found at site of M02 mortality.

Population Size, Density, and Reproductive Success

Trapping was conducted on the 18 “ladder” grids (Figure 2) from July through September 2009. A total of 69 foxes were trapped, and density estimates for the grids ranged from 0.3–1.5 foxes/km² (Table 7). When the average density of 0.86 foxes/km² was applied to the island area (216 km²), the estimated island-wide adult population was 187 foxes, with a confidence interval of 140–233 and a coefficient of variation of 0.20 (Table 8). Including pups in the analysis resulted in an island-wide population estimate of 389 foxes (80% CI = 313–466). The sex ratio was close to even for both pups and adults on the grids (Table 9). However, the ratio of pups to females was low (0.69), possibly because when the grids were trapped, pups were not yet very active outside the area immediate to dens. Targeted trapping was conducted from August 2009 through January 2010 on 29 transects in order to vaccinate foxes and replace/add radio collars. During that effort, 71 additional foxes were trapped, and the pup/female ratio from the combined trapping effort (Table 10) was higher (1.12 pups/ female), and likely more representative of the reproductive effort in 2009. The pup sex ratio from the combined effort slightly favored females, whereas that for adults slightly favored males.

Table 7. Adult density estimates for ladder grids, Santa Rosa Island, 2009.

Grid	Date Trapped	Individuals	Density (foxes/km)	SE	CV
Pocket Field	7/8–7/13	1	0.86	1.268	1.47
Bee Canyon	7/8–7/13	2	0.56	0.5292	0.94
Signal Road	7/15–7/20	4	1.17	0.7786	0.67
China Camp	7/22–7/29	4	0.88	0.6574	0.75
Burma Road	7/22–7/29	3	0.87	0.6591	0.76
Arlington Springs	7/22–7/29	2	0.58	0.5395	0.93
Trancion Canyon	7/29–8/3	4	0.59	0.5425	0.92
Lighthouse	8/5–8/10	3	0.60	0.5471	0.91
Johnson's Lee	8/5–8/10	2	0.58	0.5382	0.93
Wreck Canyon	8/12–8/17	1	0.30	0.4206	1.42
Quemada	8/13–8/17	9	0.93	0.7074	0.76
Dry Canyon	8/19–8/24	7	1.75	0.9876	0.56
Arlington Canyon	8/19–8/24	4	1.17	0.7733	0.66
Brockway Road	9/2–9/7	6	1.47	0.8877	0.60
Carrington	9/2–9/7	6	0.59	0.5413	0.92
Sierra Pablo	9/2–9/7	2	0.58	0.5346	0.92
Cherry Canyon	9/9–9/14	6	1.20	0.7713	0.65
Old Ranch Canyon	9/9–9/14	3	0.86	0.6517	0.75
Average			0.86		0.20

Table 8. Island-wide density and population estimates, 2009, San Miguel and Santa Rosa Islands.

	Captures	Individuals	Avg. Density	SE	N	80% CI	CV
<i>San Miguel</i>							
Adults	114	64	6.64	0.98	256	207–304	14.8
Pups Included	176	79	8.23	1.03	318	267–368	12.5
<i>Santa Rosa</i>							
Adults	111	51	0.86	0.17	187	140–233	19.5
Pups Included	148	69	1.8	0.27	389	313–466	15.4

Table 9. Number of foxes captured, by age and sex, on 18 Santa Rosa grids, 2009.

	Male	Female	Total
Pups	8	10	18
Adults	25	26	51
Total	33	31	69

Table 10. Number of foxes captured, by age and sex, on 18 Santa Rosa grids and 29 transects, 2009–2010.

	Male	Female	Total
Pups	21	26	47
Adults	51	42	93
Total	72	68	140

Density of Island Spotted Skunks

We have marked individual skunks with PIT tags since 2006, and so we were able to estimate density of skunks on the island using program DENSITY and the grid trapping data. The resulting estimates are for all skunks, since adults could not be distinguished from juveniles. The number of individual skunks, and thus the density, varied on the 18 ladder grids (Table 11). Applying the average density of 12.3 skunks/km² to the island's area (216 km²) resulted in an island-wide density estimate of 2,649 skunks, with an 80% confidence interval of 2,213–3,085 and coefficient of variation of 0.129. With an island-wide estimate of 389 foxes, skunks were almost 7 times as abundant as foxes.

Table 11. Density of island spotted skunks on ladder grids, Santa Rosa Island, 2009.

Grid	Date Trapped	Individuals	Density (skunks/km ²)	SE	CV
Pocket Field	7/8–7/13	2	3.9	3.1329	0.812
Bee Canyon	7/8–7/13	1	2.2	2.8356	1.317
Signal Road	7/15–7/20	10	19.5	6.515	0.334
China Camp	7/22–7/29	8	15.7	5.8666	0.374
Burma Road	7/22–7/29	6	11.7	5.0655	0.434
Arlington Springs	7/22–7/29	7	13.7	5.49	0.400
Trancion Canyon	7/29–8/3	5	9.7	4.62	0.478
Lighthouse	8/5–8/10	10	19.8	6.61	0.334
Johnson's Lee	8/5–8/10	5	9.7	4.62	0.478
Wreck Canyon	8/12–8/17	5	9.9	4.73	0.479
Quemada	8/13–8/17	10	19.3	6.46	0.334
Dry Canyon	8/19–8/24	10	19.4	6.50	0.334
Arlington Canyon	8/19–8/24	12	23.7	7.24	0.306
Brockway Road	9/2–9/7	6	11.5	5.01	0.434
Carrington	9/2–9/7	9	17.2	6.07	0.352
Sierra Pablo	9/2–9/7	4	7.8	4.24	0.540
Cherry Canyon	9/9–9/14	13	24.9	7.32	0.294
Old Ranch Canyon	9/9–9/14	6	11.6	5.05	0.434
Average			12.3		

The relative number of foxes and skunks trapped during annual monitoring suggests that skunks, although still very abundant, are starting to decline as the Santa Rosa fox population recovers (Table 12, Figure 13). Both the number of total captures and the number of total individuals indicates that since 2006 the relative abundance of foxes has increased, whereas that of skunks has decreased. Given the 2009 skunk population estimate of 2,649 and the apparent decline in skunks, the skunk population in previous years may have been as high as 4,000.

Table 12. Number of island foxes and island spotted skunks trapped during annual population monitoring, 2004–2009. Individual skunks were not marked until 2006.

Year	Foxes		Skunks	
	Captures	Individuals	Captures	Individuals
2004	44	16	158	
2005	46	22	67	
2006	104	39	425	337
2007	115	48	293	257
2008	261	96	628	444
2009	294	140	445	180

Vaccination of Wild Foxes

Of the 140 foxes trapped during grid and transect monitoring in summer/fall 2009, 113 were vaccinated against rabies and 132 were vaccinated against distemper. On Santa Rosa, as on San Miguel we have been following the guidelines for small populations (< 100), that all foxes should be vaccinated for both CDV and rabies. Although the adult population is well above 100 foxes, we will continue to use those guidelines. The alternative is the “vaccinated core” strategy, as previously described. However, in a trapping season on Santa Rosa we are unlikely to trap and handle 80–100 foxes in one portion of the island (in 2009, we handled 140 island-wide). Additionally, 10–20 collared juvenile foxes should remain unvaccinated, to act as sentinel animals for detection of pathogen outbreaks. During the 2010 trapping season we will establish a sample of unvaccinated, collared sentinel animals.

In 2009, blood samples were collected from 104 Santa Rosa foxes that had not been caught previously.

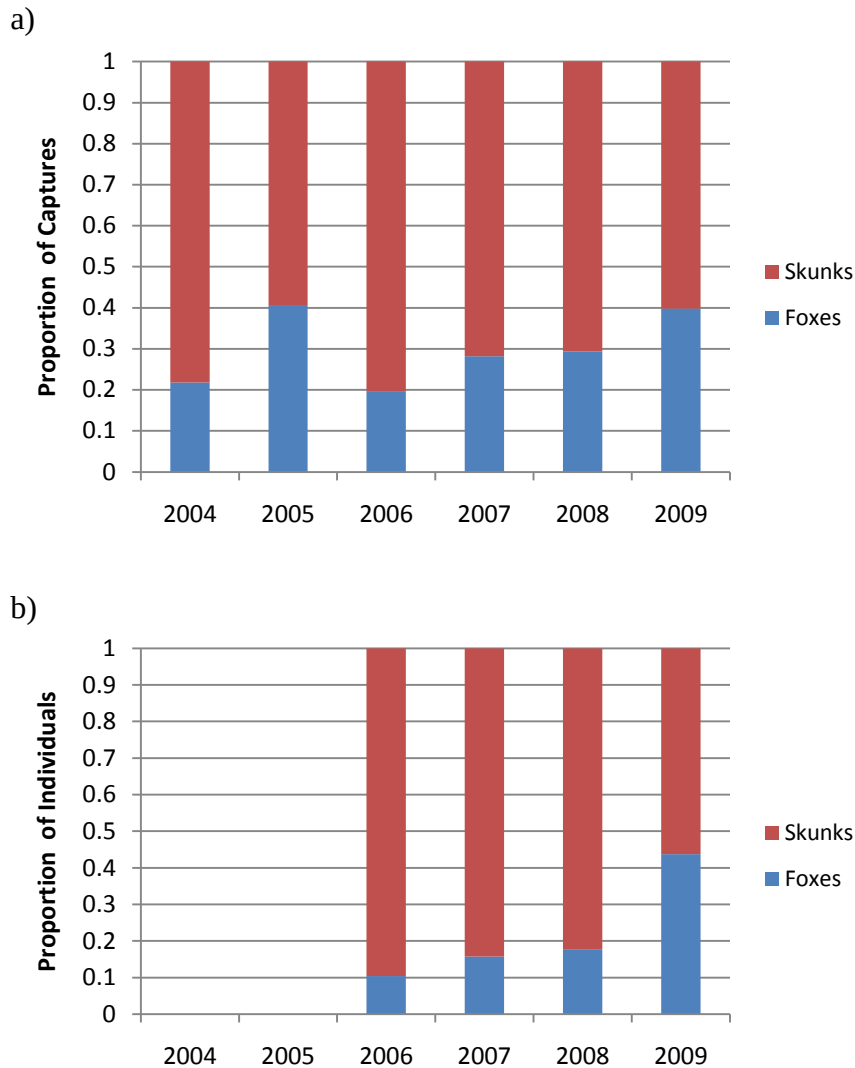


Figure 13. Proportion of captures (a) and individuals (b) for island foxes and island spotted skunks trapped during annual population monitoring on Santa Rosa Island, 2004–2009.

Future Plans

Conducting trapping on ladder grids in 2009 allowed estimation of Santa Rosa Island fox density and population size, with somewhat surprising results: adult population size was estimated to be 187, with an overall population estimate of 389 when pups were included, and wild reproduction remained relatively high. These population levels are in the range of those required for recovery, provided adult survival remains high (Bakker and Doak 2009). The latter, however, dipped to near 60% in spring 2010 due to eagle predation. Grid monitoring and density/population estimation in 2010 will indicate whether the recent eagle predation affected the trajectory of population recovery.

Recovery actions will continue in 2010. We will maintain a sample of >50 radio-collared foxes (Bakker and Doak 2008) on the island. We will conduct population monitoring in summer/fall

2010, using small, “ladder” grids (Rubin et al. 2007). All newly encountered wild animals will be PIT-tagged, and all captured foxes will be vaccinated against canine distemper virus and rabies. If we reach the point where we are handling well over 80–100 animals annually, we will consider shifting to the “vaccinated core” strategy, in which a portion of the number of foxes caught annually is vaccinated against canine distemper virus. As discussed previously, this would allow circulation of the naturally occurring strain of canine-distemper virus (Clifford et al. 2006).

Cooperative Studies

In 2009 the NPS participated in the following island fox studies, which utilized park staff, park island fox samples, or park data:

Island Fox Foraging Ecology Study

Principal Investigator: Brian Cypher, California State University, Stanislaus

Habitat Utilization by Male Island Foxes

Principal investigator: Lisa Drake, California State Polytechnic University, San Luis Obispo

Use of Proximity Collars to Investigate Social Interactions among Island Foxes

Principal Investigators: Brian Cypher, California State University, Stanislaus
Kathy Ralls, Smithsonian Institute

The Zoonotic Bacterium Bartonella in Island Foxes

Principal Investigator: Bruno Chomel, University of California, Davis

Vector-borne Pathogens in Santa Rosa Island Foxes

Principal Investigator: Mourad Gabriel, University of California, Davis

Parasites and the Pattern of Carnivore Distribution across North America

Principal Investigator: Nyeema Harris, North Carolina State University

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The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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