



Island Fox Recovery Program

Channel Islands National Park 2011 Annual Report

Natural Resource Report NPS/MEDN/NRR—2012/572



ON THE COVER

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

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Executive Summary

In 2011 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*). Results from annual monitoring indicate that both populations continue to increase and have high annual survival. The San Miguel subspecies has returned to pre-decline population levels, and can be considered biologically recovered. The Santa Rosa subspecies is currently at about one fourth of its likely pre-decline level.

A 10-year program of captive breeding and release of both subspecies was completed in 2008. The San Miguel captive breeding facility was closed in 2007, and the Santa Rosa captive facility was closed in 2008 after the final release of captive foxes in November of that year. 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 park's island fox program is currently in an intensive monitoring phase designed to insure that recovery continues apace, and to eventually document attainment of criteria which would allow delisting of the two subspecies. The excellent survival and reproduction in the wild allowed rapid growth of the small, recovering populations, and by the end of 2011 the San Miguel island fox population estimate was 393 adults (Fig. 1) and 581 total foxes, numbers which are comparable to population levels prior to the predation-caused decline of the 1990s. The Santa Rosa fox population had decreased in 2010, due to predation in spring of that year. In 2011 the Santa Rosa population estimate was 280 adults, and 449 total foxes (adults and pups). Thus in 2011 the San Miguel and Santa Rosa populations increased by 24% and 66%, respectively.

Annual survival of released and wild-born foxes continued to be high on San Miguel (91%), and only 5 radiocollared foxes died on San Miguel in 2011, none from eagle predation. Annual survival on Santa Rosa was 90% in 2011, compared to 66% in 2010, when eagle predation increased mortality. Seven radiocollared foxes died on Santa Rosa in 2011, with predation being cause of mortality for two of those foxes. Genetic analysis of feathers found at kill sites in 2010 indicated that those mortalities were the handiwork of three subadult eagles, who were likely related. In 2011 there were no mortalities due to leptospirosis (in 2010 there were two). Results of culturing urine samples from Santa Rosa Island foxes and island spotted skunks (*Spilogale gracilis amphiala*) identified the *Leptospira* serovar as *Leptospira interrogans* Pomona, which is identical to the strain isolated from California sea lions (*Zalophus californianus*) in 1970. That pinniped species is thought to be a maintenance host of *Leptospira*, and it is unclear whether foxes and skunks are also maintenance hosts, or alternatively, whether they are accidental hosts. Seroprevalence of *Leptospira* in Santa Rosa adult island foxes was 69% in 2009

and 84% in 2010; titers to *Leptospira* were not detected in San Miguel island fox samples from either year.

We conducted grid trapping in summer-fall 2011 to monitor the wild populations on each island. On San Miguel we trapped foxes on 4 small (3 x 6 trap) grids, in order to estimate fox density, replace radiocollars, gauge reproduction through capture of pups, vaccinate wild foxes, and check physical conditions. A total of 82 individuals were trapped on the grids in 2011. The adult density estimates for the 4 grids, as calculated with program Density, were 10.3, 11.2, 5.8 and 13.5 foxes/km², with average adult density being 10.2 foxes/km². The average annual rate of increase (lambda) for the San Miguel island fox population for 2004 (when reintroductions ended) through 2011 is 1.53.

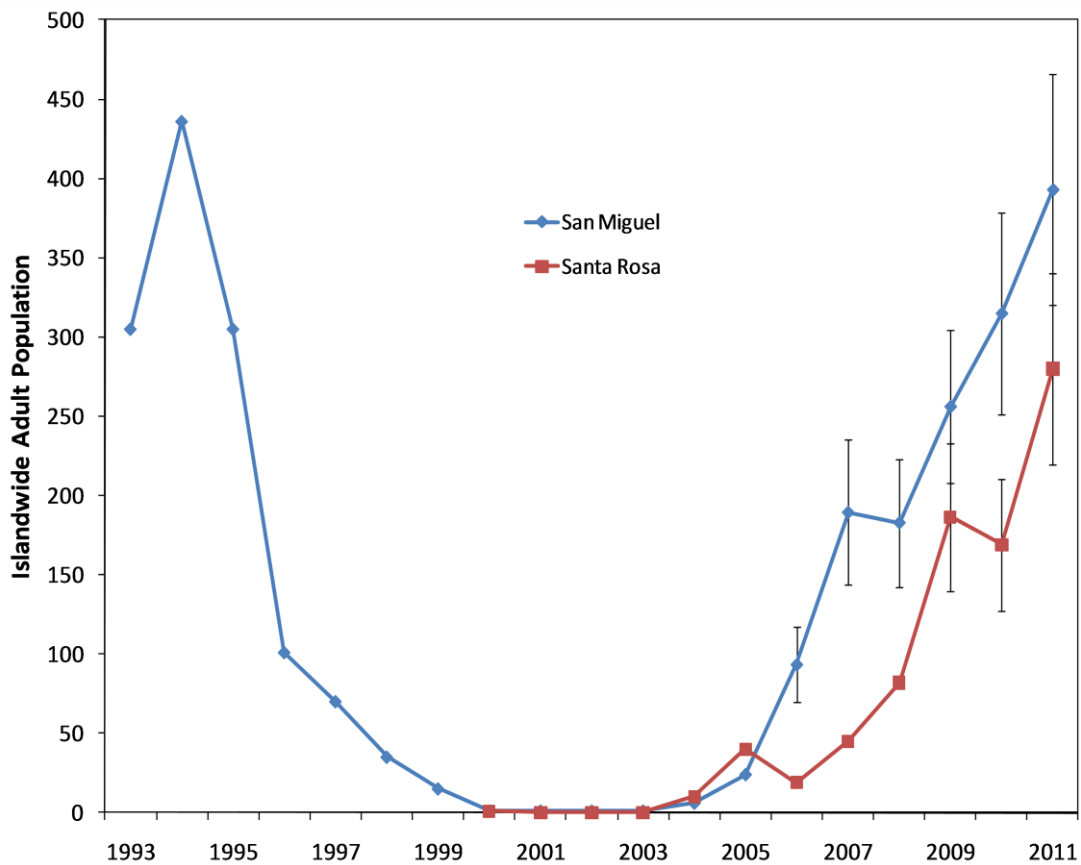


Figure 1. Annual estimated number of adult island foxes for San Miguel and Santa Rosa. Pre-decline estimates are not available for Santa Rosa; 80% confidence intervals are shown for estimates from program Density.

A total of 26 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 (19). The estimated reproductive success of 1.4 pups per female was lower than last year's estimate (1.9), perhaps a density-dependent effect of the population approaching pre-decline numbers. Reproductive success has generally declined as the wild fox population has grown.

From 2004-2008, trapping on Santa Rosa was conducted on transects, which precluded estimation of density and islandwide population size. In 2009 we began conducting trapping on 18 randomly located small “ladder” grids, as recommended by Rubin et al. (2007). In 2011 average density on the 18 grids was 1.3 foxes/km², and resulting population estimates represented a >60% increase from 2010 population estimates, which were lower due to eagle predation in spring 2010. The reproductive effort was 0.93 pups/female, which was similar to the previous year’s estimate (0.78).

As in 2009 and 2010, we were able to estimate the size of the island spotted skunk 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 14.7 skunks/km² and an islandwide estimate of 3,166 skunks. This is comparable to the estimates for 2009 and 2010 (3,013 and 2,910 skunks, respectively). 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 2011 and previous years indicate that skunks are decreasing as the fox population recovers. When foxes were absent from the wild on Santa Rosa, there may have been over 4,000 skunks on the island.

Almost 90% of trapped foxes were vaccinated against rabies, and 70% against canine distemper virus (CDV). Number of vaccinates for rabies was 113 on San Miguel and 145 on Santa Rosa, while the number of foxes vaccinated against CDV was 101 and 107, respectively. We do not encounter and handle enough foxes to follow the ‘vaccinated core’ strategy, in which 80-100 foxes in one area of the island are vaccinated against CDV (which allows for natural immunity from the endemic strain of CDV in island foxes). We continue to follow the “small population” strategy of vaccinating almost all animals against both diseases.

In 2011 we conducted a serosurvey on island fox blood samples collected in 2010. A total of 135 blood samples were collected, 69 from San Miguel and 66 from Santa Rosa. None of the samples tested positive for canine parvovirus (CPV), and only one, from San Miguel, tested positive (weakly so) for CDV. Thirty-one samples from San Miguel and 2 from Santa Rosa tested positive for canine adenovirus (CAV). High seroprevalence to CAV had been observed before in the San Miguel and Santa Rosa subspecies, with no apparent consequences for individuals or the population, and so this does not indicate a situation which requires intervention.

Acknowledgements

We would like to thank our dedicated island fox crew for gathering the data for this report. Because of their efforts we have excellent information on the status and trend of island fox populations in the park. Island fox staff in 2011 comprised Jen Savage, Ryan Munes and Renae Sattler; they were capably supervised by Helen Fitting.

In 2011 we benefited from the work conducted by a number of volunteers: Liz Beem, Ria Boner, Maria Cordero, Paul Durst, Wes Hardin, Joel Justin, Stephanie Klein, Jose Manual Mora, Lauren Perry and Robyn Shea.

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Thanks to Brett West for facilitating purchase of supplies and materials for the fox program. The generosity and fundraising capabilities of Patricia Meyer and her Friends of the Island Fox Foundation continue to be much appreciated. That group has donated dozens of radiocollars and funds for vaccinations and vet checks to the park island fox recovery program.

Transportation to the islands was smoothly coordinated by Park dispatchers Sean Carr and Renee Denley, and boat transportation was conducted by Dwight Willey, Keith Duran and Diane Brooks. Rangers Ian Williams, Mark Senning and Lulis Cuevas provided on-island support for fox monitoring and management.

We appreciate the continued support of the Island Fox Conservation Working Group, whose support and critical review over the years has focused and improved our recovery efforts.

Island fox recovery at the park would not be possible without the continued support of Kate Faulkner, Russell Galipeau, and Dave Graber.

Introduction

Background

The island fox, a diminutive relative of the gray fox (*Urocyon cinereoargenteus*), is endemic to the California Channel Islands. The fox is recognized as a 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 Channel Islands National 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 (Coonan et al. 2010). 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.

Evidence from radiotelemetry studies showed that predation by golden eagles was the primary mortality factor for island foxes on the northern Channel Islands, and caused the massive decline of the three northern subspecies from 1994 to 2000 (Roemer et al. 2001). Golden eagle predation was identified as the cause of death for 19 of 21 radiocollared island foxes on Santa Cruz Island from 1993 to 1995 (Roemer et al. 2001). 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. 2005b).

Until the 1990s, golden eagles had 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. 2001). 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.

Recovery Actions

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 the summer of 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 one in the wild. Four of the captured foxes were males and 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 because of 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 the mid-2000s the Park and its partners implemented larger-scale ecosystem restoration actions that resulted in long-term benefits for island foxes. In 2005–2006 the Park and the Nature Conservancy cooperated to remove feral pigs (>4,000 total) from Santa Cruz Island, thereby eliminating that non-native golden eagle prey source. The restoration of bald eagles to the northern Channel Islands, funded by the Montrose Settlements Restoration Program,

comprised annual releases of young eagles from 2002-2006. Breeding by released bald eagles began in 2006, and as of 2012 there were >40 bald eagles on the northern Channel Islands, with breeding occurring on Anacapa, Santa Cruz and Santa Rosa Islands.

In 2003, the Park completed a recovery strategy for island foxes on the northern Channel Islands (Coonan 2003). The recovery strategy was 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. 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, Coonan et al. 2010). 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 has now eliminated the last of the non-native prey base from the northern Channel Islands.

Ecological Effects of Changes in Fox Abundance

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 annually convened a group of experts 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 (IFCWG) 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 IFCWG. 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.

Island Foxes and Long-term Ecological Monitoring

Island foxes have been monitored at Channel Islands National Park since 1993, when annual population monitoring of San Miguel Island foxes was begun as a result of the Park being designated as a Prototype Park for the NPS Inventory and Monitoring Program (Davis et al. 1994). The park was one of a handful at which such comprehensive ecological monitoring was initiated. Island foxes were chosen to monitor because the species was the largest native terrestrial vertebrate on the islands, was endemic to them, and existed at population sizes small enough to render them vulnerable to disease or stochastic demographic declines. The decision to

monitor island foxes proved prescient when the monitoring program detected the predation-caused massive decline of San Miguel Island foxes in the mid to late 1990s (Coonan et al. 1998, 2005b).

The early population monitoring, now considered a legacy monitoring protocol, utilized large (7 x 7) grids to estimate island fox density (Fellers et al. 1988, Roemer et al. 1994). That monitoring ended in 1999, when the remaining foxes on San Miguel (15 individuals) were brought into captivity. Current island fox monitoring methods were borne of the 10-year island fox recovery effort (Coonan et al. 2010), in addition to the basic monitoring conducted through the I&M Program. These methods, which have been used since foxes were first reintroduced to the wild in 2003/2004, utilize smaller grids to estimate density, and couple that with mortality monitoring via radiotelemetry (Coonan et al. 2005a). The latter began in 1998, during the final stages of the decline, and was used to identify golden eagle predation as the cause of the decline. Mortality monitoring and annual density estimation are currently viewed as appropriate, and even necessary, for tracking island fox recovery and for detecting future threats to island foxes (Rubin et al. 2007), and are being implemented on all six islands where foxes exist. The park's current methods for monitoring foxes will be described in detail and subjected to peer-review in an NPS island fox monitoring protocol to be published by the NPS I&M Program.

This report covers island fox recovery actions conducted by park staff in calendar year 2011. 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 2012). 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).

This report presents the results of our efforts in 2011 to capture and monitor island fox populations on San Miguel and Santa Rosa Island via small trapping grids and transects, and to track annual survival and mortality causes via radiotelemetry. The purpose of the monitoring was to:

- assess condition of individual foxes
- replace radiocollars or affix new radiocollars as required
- establish a "sentinel" group of unvaccinated, radiocollared animals
- vaccinate foxes against canine distemper virus and rabies
- estimate density and islandwide population size

Methods

Population Monitoring of Wild Foxes

On San Miguel, grid trapping for density estimation was conducted in September, and transect trapping to manage collars, establish sentinels and administer vaccines was conducted from September through December. On Santa Rosa, grid trapping was conducted July - September, and transect trapping from July through December. In both cases 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.

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. 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.

Grid trapping data was used to estimate distribution and abundance of island foxes, through such measures as trapping success, age structure and sex ratio of foxes, and reproductive success (ratio of number of pups to number of adult females). To estimate density and islandwide population size, 4 small (3 x 6) grids (Fig. 2) 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. Despite the somewhat selective placement of the grids, we assume the grids are representative of the island as a whole. Representation of habitat types by the grids is similar to that of the large grids sampled in the 1990s. Although the new grids sample areas with lower slope and ruggedness than the island as a whole, that would be true for any trapping scenario, since the rugged cliffs at the island's edge are unsafe to sample (Rubin et al. 2007).

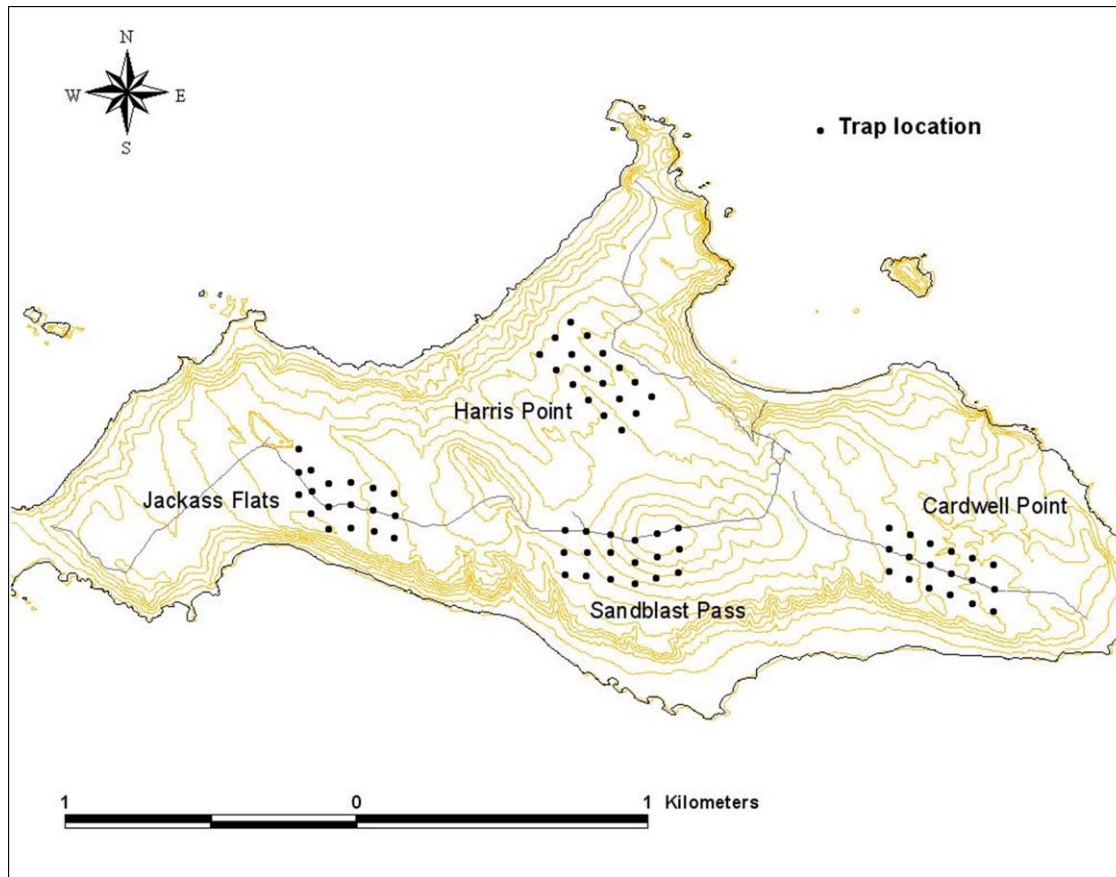


Figure 2. Location of trapping grids, San Miguel Island.

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 2-person crew could trap one grid per week while still performing other duties (such as monitoring radiocollared foxes). The grids were run for 5 nights.

Previous population monitoring on Santa Rosa utilized line transects, from which it is difficult, if not impossible, to estimate density and thus islandwide population size. Therefore in 2009 we shifted to grid monitoring, and established 18 “ladder” grids (Fig. 3), each comprising a 2 by 6 trap array, as recommended by Rubin et al. (2007). Each grid was run for 6 nights.

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).

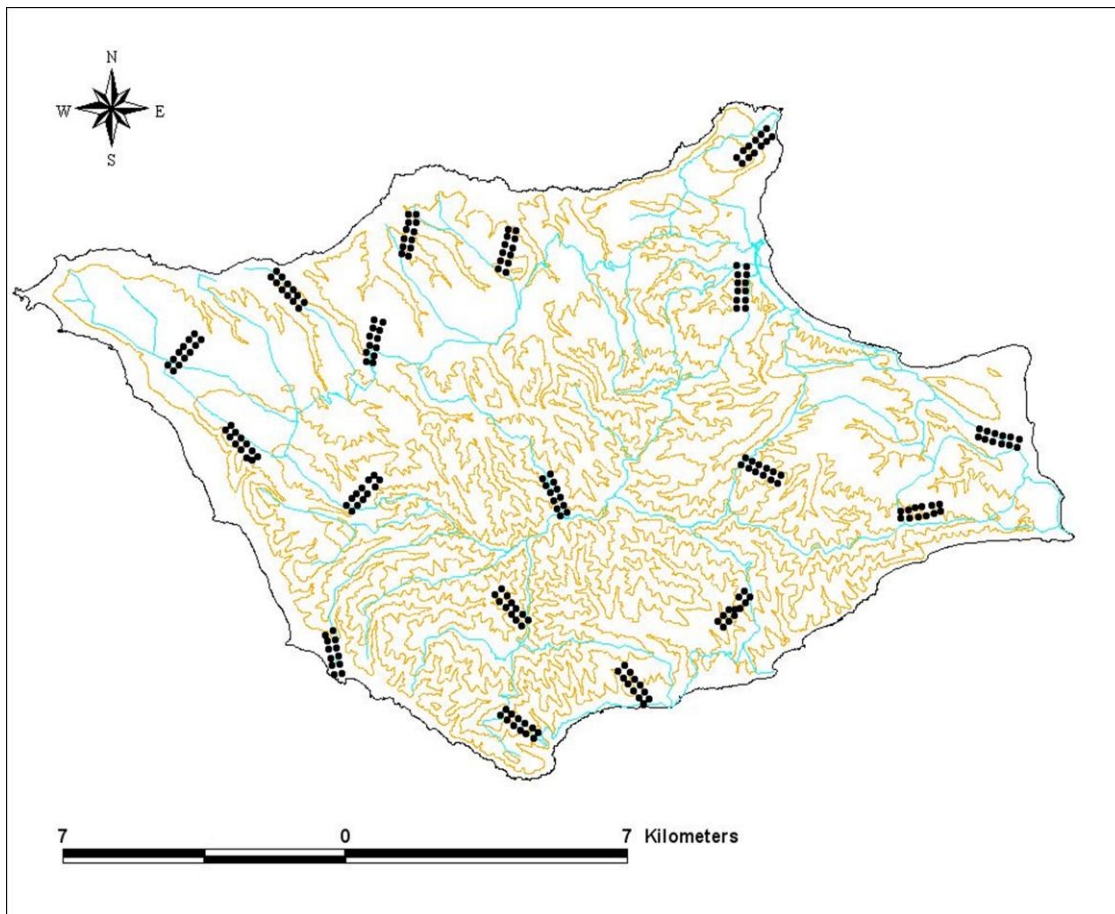


Figure 3. Location of 18 "ladder" grids, Santa Rosa Island.

During trapping on Santa Rosa, we also marked island spotted skunks with PIT tags, and so were able to estimate skunk density and islandwide population size.

Survival and Mortality Causes

On both islands, mortality-sensing radio-telemetry collars (Holohil Systems Ltd., Ontario, Canada) were placed on a subset of captured foxes in order to assess mortality rates and factors. Collared foxes were monitored regularly 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 carcasses 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 California Animal Health & Food Safety Laboratory System in Davis, California (Leslie Woods, DVM) 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.

Annual survival of radiocollared foxes was estimated with the non-parametric Kaplan-Meier procedure with staggered entry of 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 (V. Bakker, James Madison University, and D. Doak, University of Wyoming, pers. comm.).

For both subspecies we used the islandwide population estimate and annual mortality ($1 - \text{annual survival}$) 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 3-year averages of adult population size and adult annual mortality to determine if those values resulted in acceptable extinction risk (5% over 50 years). We used a spreadsheet tool developed by Vicki Bakker of James Madison University. The tool plots current values against isoclines representing various levels of extinction risk for island foxes on each island (Bakker and Doak 2009).

Vaccination of Wild Foxes and Establishment of Sentinel Animals

A subset of captured foxes was vaccinated against canine distemper virus and rabies. Although vaccination of wild animals in national parks is rare, vaccination is the best strategy for mitigating possible outbreaks of CDV and rabies in island foxes, because a decline would not be detected quickly enough through monitoring of radiocollared foxes (see below). Consequently, the IFCWG has recommended that 80-100 foxes on each island be vaccinated against CDV, and all captured foxes should be vaccinated against rabies (see Appendix A in Coonan 2010). Not all foxes are vaccinated against CDV in order to protect the naturally-occurring CDV-like morbillivirus that circulates in island fox populations and provides some immunity (Clifford et al. 2006). Selected animals were vaccinated with Purevax Ferret Distemper Vaccine for CDV and Imrab 3 for rabies (Merial, Inc., Atlanta, GA).

In 2011 we continued to establish a sample of radiocollared sentinel animals on each island. In order to detect disease outbreaks (other than CDV or rabies) the IFCWG has recommended that each island have up to 20 juvenile (1-2 year old) foxes that are unvaccinated (see Appendix A in Coonan 2010). As our wild populations on San Miguel and Santa Rosa have grown, it has become possible to establish sentinels on both islands. During trapping season in 2011 we affixed radiocollars to a number of unvaccinated juvenile foxes for this purpose.

Serologic Survey

Island fox blood samples were analyzed by Dr. Edward Dubovi at Cornell University's Animal Health Diagnostic Center for presence of antibodies to canine adenovirus (CAV), canine distemper virus (CDV) and canine parvovirus (CPV). Tests for CAV and CDV utilized the virus

neutralization antibody test, for which results are reported as the reciprocal of the highest dilution of serum that neutralizes the infectivity of the virus. Individuals with antibody titers $\geq 1:16$ were considered to be positive. Minimum readable dilution was 1:4 for both CAV and CDV. The test for CPV utilized the hemagglutination inhibition antibody titer and results are reported as the highest dilution of serum that prevents the agglutination of red blood cells by parvovirus, with minimum dilution being 1:20.

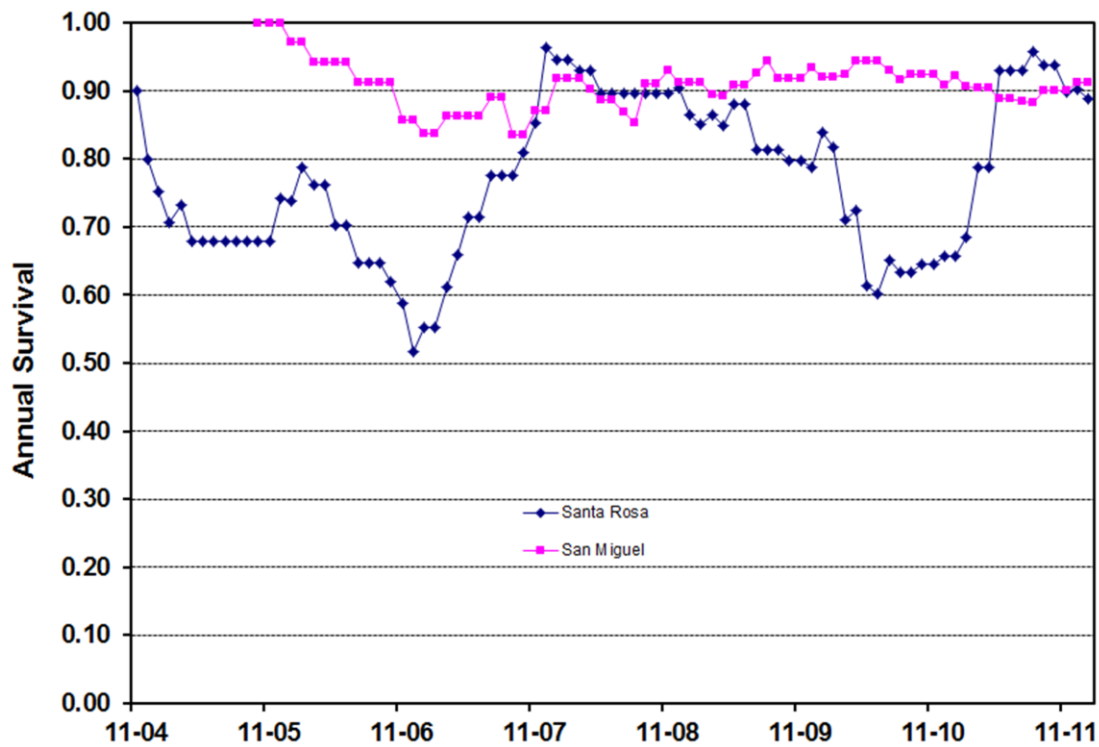


Figure 4. Rolling annual Kaplan-Meier survival for island foxes, San Miguel and Santa Rosa islands.

Results and Discussion

San Miguel Island

Mortality Monitoring

Throughout 2011 we maintained a sample of 51-66 radiocollared foxes on San Miguel, and by the end of the year there were 66 radiocollared foxes being monitored. Annual Kaplan-Meier survival for San Miguel island foxes in 2010 was 91.0% (80% CI = 87-95%). Annual survival has remained above 80% since foxes were first released on San Miguel in 2004 (Fig. 4). Five radiocollared foxes died in 2011, none from eagle predation (Table 1). Carcasses were too decomposed for necropsy.

Table 1. Island fox mortalities, San Miguel Island, 2011.

PIT Tag	ID	Sex	Born	Age	Died	Mortality Cause
03A13	F305	F	Captive	7	1/3/2011	Unknown
4052B	M255	M	Wild	4	3/1/2011	Unknown
E473A	F347	F	Wild	3	4/16/2011	Unknown
B614D	F360	F	Wild	3	6/19/2011	Unknown
01E1A	F359	F	Wild	2	8/1/2011	Unknown

Table 2. Adult density estimates for small grids, San Miguel Island, 2011.

Grid*	Date Trapped	Individ.	Density (foxes/km ²)	SE	CV**
CHAR	9/7 – 9/11	8	5.8	2.189	0.38
SAND	9/15 – 9/19	19	13.5	3.438	0.25
CARD	9/24 – 9/28	14	10.3	2.989	0.29
JACK	9/24 – 9/28	15	11.2	3.158	0.28
average			10.2		

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

**Coefficient of Variation = standard deviation/mean

Wild Population Monitoring

Grid trapping in summer/fall 2011 yielded the following measures of population health:

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

The 4 small grids were trapped from early through late September and a total of 82 individuals (26 pups and 56 adults) were trapped. Adult density on the 4 grids ranged from 5.8–13.5 foxes/km², with an average density of 10.2 foxes/km² (Table 2). The coefficient of variation for

the islandwide density estimate was 0.15 (a CV < 0.20 is desirable [M. Efford, Landcare Research, pers. comm.]). Multiplying the average density by the area of the island (38.1 km²) yielded a population estimate of 393 adult foxes, with 80% CI = 320-467 adult foxes. When pups were included in density estimates, the islandwide population estimate was 581 foxes, with 80% CI = 493-670.

Since reintroduction began in 2004, the wild island fox population has increased (Fig. 5) due to annual reintroduction (2004-2007) and to reproduction in the wild. The annual rate of increase (λ , or lambda) was >2.0 in 2006 and 2007, and declined to <1.0 in 2008, and was > 1.20 since then. (Table 3). Average λ was 1.53 and annual values of λ have generally declined over time as the population has increased. Values of λ >1.0 indicate an increasing population.

Table 3. Islandwide adult population estimate from grid density estimates (2006-2011) and from transect trapping (2005), San Miguel Island.

	N	SE	Variance	80% CI	lambda
2005	40*				
2006	93	18.58	345.280	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
2010	315	49.77	2476.53	252-379	1.23
2011	393	57.52	3308.901	320-467	1.24

*Minimum number known to be alive from trapping and radiotelemetry

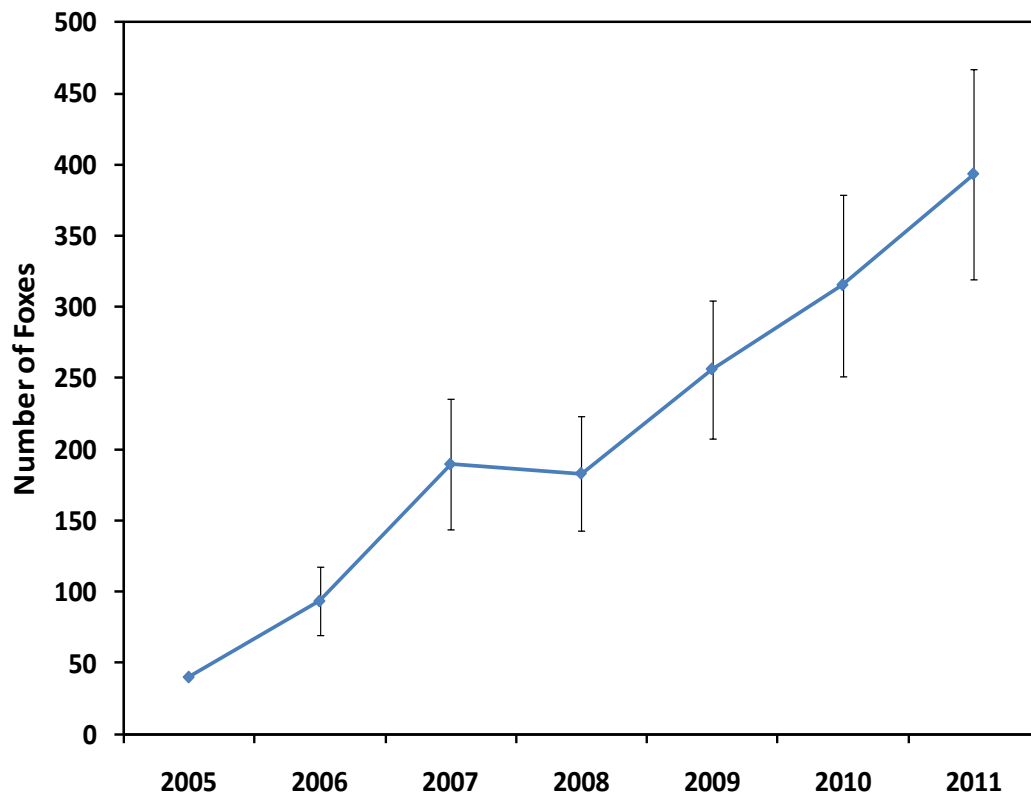


Figure 5. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2011).

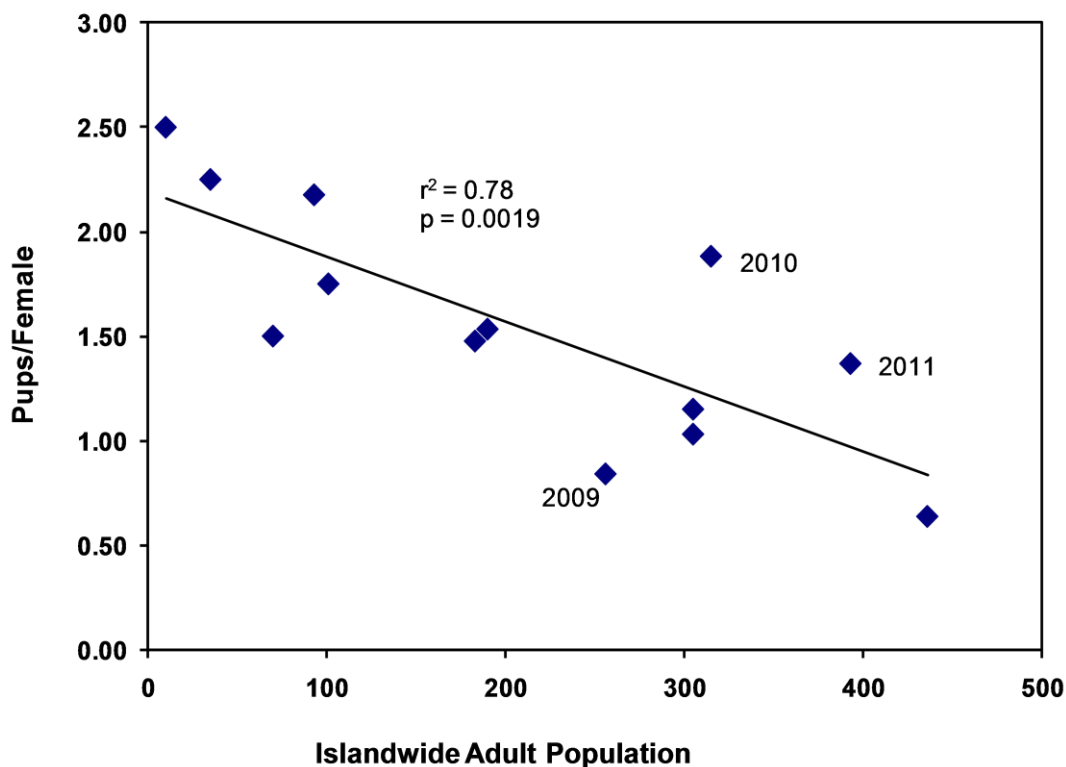


Figure 6. Regression of reproductive effort (pups/adult female) on islandwide population size, San Miguel Island, 1993-2011.

A tally of captured foxes by sex and age indicated an equal sex ratio in pups and a bias toward males in adults, similar to 2010 (Table 4). We measured reproductive success as the ratio of pups (26) to number of adult females (19) captured on the grids. The estimated reproductive success of 1.4 pups/female was relatively high, given that density and population level was high. When plotted with values from other years (including data from 1993-1999, encompassing the population decline), the regression of reproductive effort on adult population size showed reproductive effort declining as population increases, a density-dependent effect (Fig.). Values for 2010 and 2011 fell above the regression line, indicating better than expected reproductive effort, given the high fox densities.

Table 4. Number of foxes captured, by age and sex on 4 grids on San Miguel, 2011.

	Male	Female	Total
Pups	12	14	26
Adults	37	19	56
Total	49	33	82

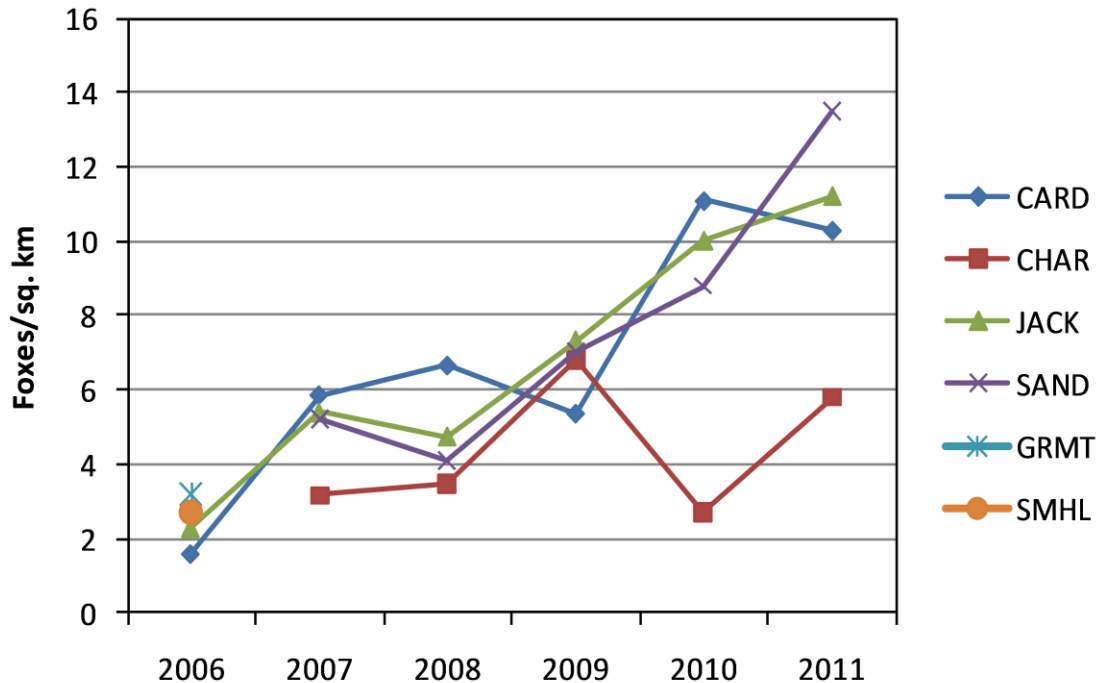


Figure 7. Adult fox density (foxes/km²) on individual grids, San Miguel Island, 2006-2011.

Average density and islandwide population estimate have steadily increased on San Miguel, and this has also been true for all the individual grids save Harris Point (Fig. 7). It may be that the Harris Point area, with its high winds and low vegetation communities, does not comprise high-quality habitat for island foxes.

Because grid placement on San Miguel was not truly randomized (see Methods), density estimates derived from trapping on the grids may be overestimating density, and thus islandwide population size. The grids largely do not sample beaches and cliffs (which are too steep to sample), as opposed to upland areas. However, this has little effect on interpreting population trend, since average density from the grids has been applied to the same island area value (38.1 km²) annually. The original legacy sampling grids were not placed randomly, either, but were more than adequate to detect a declining population trend in San Miguel Island foxes (Roemer et al 1994, Coonan et al. 2005b). Also, neither topography nor vegetation (habitat type) is as varied on San Miguel as it is on larger islands which foxes occupy, minimizing potential bias in the sampling.

Plots of recent values of population size and mortality rate against isoclines of extinction risk continued to be encouraging. The plots of 3-year averages for 2008, 2009, 2010 and 2011 (Fig. 8) show that the 80% confidence limits for both mortality and population size fell increasingly below the 5% isocline, which is the acceptable level of risk identified in the USFWS draft island fox recovery plan. The San Miguel population reached biological recovery in 2008, and the values for 2009, 2010 and 2011 indicate even greater probability of avoiding extinction. The draft recovery plan includes other requirements for de-listing: these levels must be reached for 5 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 has returned to pre-decline levels, and can now be considered biologically recovered.

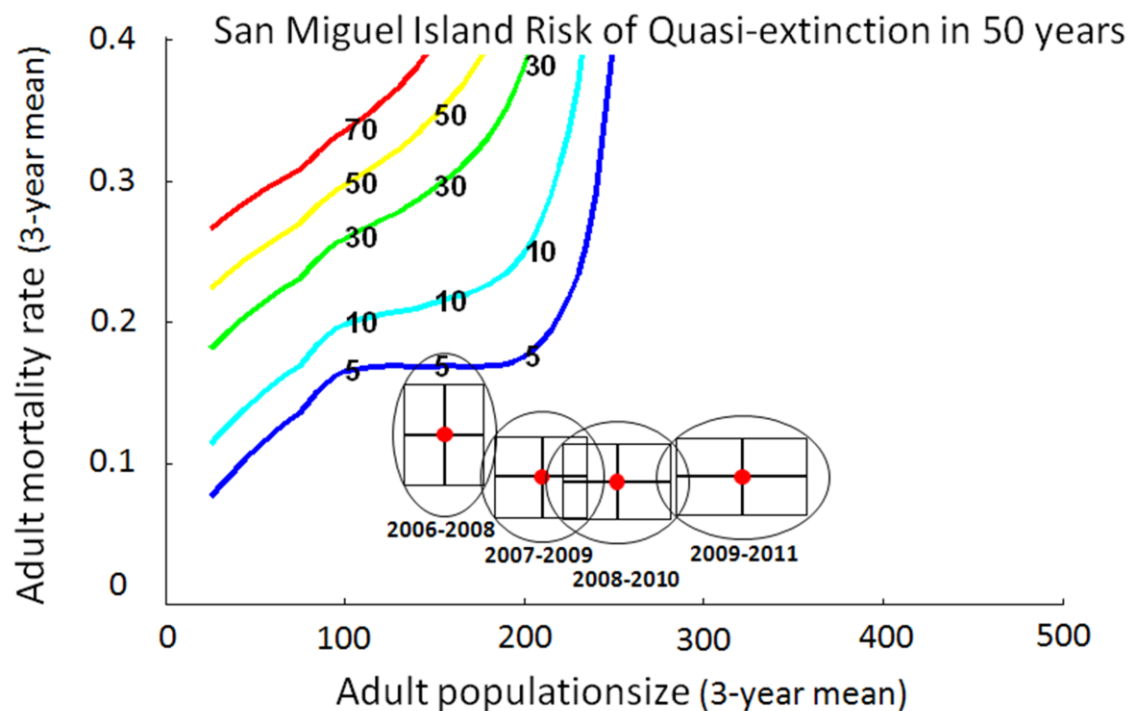


Figure 8. Extinction risk for San Miguel Island foxes under 2006-2011 averages for adult mortality and population size.

Vaccination of Wild Foxes and Establishment of Sentinel Animals

After the grids were trapped, transect trapping was conducted to manage radiocollars, establish sentinel animals for disease detection, and to vaccinate wild foxes. Between transect trapping and grid trapping, 129 foxes were captured on San Miguel in 2011. Of those foxes, 113 were vaccinated against rabies and 101 were vaccinated against distemper. On San Miguel we have been following the guidelines for small populations (< 100), which recommends that all foxes should be vaccinated for both CDV and rabies. 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, Appendix A in Coonan 2011). 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). The guidelines for vaccination recommend moving to the vaccinated core strategy when the population reaches 50% of the recovery goal. With the San Miguel population now at pre-decline levels and low demographic risk of extinction, a shift to the vaccinated core strategy should occur. However, in a single trapping season on San Miguel we are unlikely to trap and handle 80-100 foxes in one portion of the island (in 2010, we handled 129 islandwide). Additionally, 10-20 collared juvenile foxes should remain unvaccinated, to act as sentinel animals for detection of pathogen outbreaks. Thus all foxes, except sentinels, will continue to be vaccinated against rabies, since there is no

naturally occurring strain of rabies in island fox populations, and about 100 will be vaccinated against CDV.

During the 2011 trapping season we completed establishing a sample of ≥ 20 unvaccinated, radiocollared sentinel animals (Table 5). There are currently 27 sentinel animals on San Miguel; two sentinels died, of unknown cause, in 2011. We will maintain an annual sample of such disease sentinels indefinitely, in order to identify influence of pathogens on island foxes.

Table 5. Radiocollared foxes identified as disease sentinels on San Miguel Island, 2011.

ID	PIT Tag	Sex	Age Class	Date Collared	Comments
F355	00C50	F	1	8/26/2010	died 8/1/2011
F359	01E1A	F	1	10/8/2010	
M289	03547	M	0	12/29/2011	
F369	04869	F	0	9/30/2011	
M276	07B05	M	1	8/12/2010	
M285	08117	M	1	9/26/2011	died 6/19/2011
F365	13F0F	F	0	9/15/2011	
F356	15255	F	0	9/9/2010	
M287	186128	M	0	11/7/2011	
M280	52B7A	M	0	11/13/2010	
F367	54062	F	1	9/24/2011	
F358	56C06	F	1	10/8/2010	
F357	57D6C	F	1	9/7/2011	
F364	72A69	F	0	9/7/2011	
F363	73E78	F	1	12/8/2010	
F362	75104	F	0	11/27/2010	
M288	85823	M	0	11/8/2011	
F368	86024	F	1	9/26/2011	
M284	A0432	M	0	9/16/2011	
F360	B614D	F	2	11/11/2010	
M277	B7104	M	0	8/26/2010	
F366	B7D4D	F	0	9/16/2011	
F361	C2036	F	0	11/25/2010	
M281	C4F36	M	0	11/18/2011	
M281	C4F60	M	0	9/3/2011	
M279	D0522	M	0	9/22/2010	
M282	D5156	M	0	9/9/2011	
F357	D7D6C	F	0	9/22/2010	
M278	F5200	M	0	9/10/2010	

Blood Samples and Serosurvey

In 2011, blood samples were collected from 93 San Miguel foxes. We also conducted a serosurvey on island fox blood samples collected in 2009 and 2010 on San Miguel and Santa Rosa Islands. Results from Cornell University's Animal Health diagnostic Center (Table 6) indicate no exposure to canine parvovirus (CPV) on either island. One fox from San Miguel tested positive, at 1:16 dilution, for canine distemper virus (CDV). Seroprevalence to canine adenovirus (CAV) was low on Santa Rosa (2 of 66 samples tested positive), but was much higher on San Miguel, where almost half the foxes tested positive. A number of foxes had extremely high titers, suggesting recent exposure. In previous serosurveys (Garcelon et al. 1992, Roemer et al. 2001, Clifford et al. 2006), CAV has been very common among San Miguel and Santa Rosa island foxes (Table 7), as well as in San Clemente foxes, but low to nonexistent on other islands. Given this, it is puzzling that seroprevalence to CAV was relatively low in 2009-2010. It may be that seroprevalence is density-dependent. On Santa Rosa, where adult fox density is 1.3 foxes/ km², there may be less contact among foxes and hence less transmission of CAV. On San Miguel, where foxes have recovered to pre-decline levels and adult density is 10 times that on Santa Rosa, there are likely more opportunities for transmission. Canine adenovirus can potentially cause mortality in pups, but the disease has never been identified as a mortality cause in island foxes, despite several thousand necropsies of foxes from all islands (Munson 2010, in Coonan et al. 2010).

Table 6. Seroprevalence among San Miguel and Santa Rosa island foxes to three canine diseases, 2009-2010. The number of positive samples is given in parentheses.

	San Miguel n = 69	Santa Rosa N = 66
Canine adenovirus (CAV)	0.45 (31)	0.03 (2)
Canine distemper virus (CDV)	0.01 (1)	0.0 (0)
Canine parvovirus (CPV)	0.0 (0)	0.0 (0)

Table 7. Seroprevalence (proportion of sample that tested positive) to canine adenovirus among San Miguel and Santa Rosa island foxes, from previous studies.

Sampling Period	San Miguel	Santa Rosa	Source
1988	0.96	0.97	Garcelon et al. 1992
1994 - 1997	0.95	no data	Roemer et al. 2001
2001 - 2003	100.0	100.00	Clifford et al. 2006

Future Plans

Results from monitoring in 2011 indicate that the wild population on San Miguel is still in a phase of expansion, though the annual rate of increase is decreasing. Survival is high, reproductive success is relatively high, and the average rate of increase, or lambda, from 2005 to 2011 was 1.53. With the estimated adult population just under 400 and total population at almost 600 individuals, the San Miguel subspecies has finally reached what could be considered "high" population levels similar to those before the decline of the 1990s. Although captive breeding ceased on San Miguel Island in 2007, intense island fox monitoring 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 2012 on the 4 small grids to estimate population size and reproductive effort. A subset (80-100) of the foxes trapped in 2012 will be vaccinated against canine distemper virus to form a "vaccinated core" which would survive

future outbreaks. All captured foxes will be vaccinated against rabies. In 2012 we will continue to maintain our sample of sentinel animals. At least 20 juvenile (1-year old) foxes will be radiocollared but not vaccinated, in order to detect outbreaks of other types of pathogens.

Santa Rosa Island

Mortality Monitoring

Throughout 2011 we maintained a sample of 45-58 radiocollared foxes on Santa Rosa, and by the end of 2011 there were 57 radiocollared foxes on the island. Collared foxes included some released from captivity and wild-born foxes. Annual Kaplan-Meier survival for Santa Rosa Island foxes in 2010 was 90% (80% CI = 85-95%) (Fig.4). Annual survival on Santa Rosa increased considerably from that in 2010 (66%), which was relatively low due to the influence of eagle predation in spring 2010. An annual survival rate of 80% is generally required for a stable or increasing fox population (Roemer et al. 2001). Seven radiocollared foxes died in 2011, 2 from predation and 4 from unknown causes (Fig. 9, Table 8).

Genetic testing of feathers from 2010 kill sites showed that the predation that spring was likely the handiwork of three related subadult golden eagles (Sonsthagen et al. 2012).

No foxes died from leptospirosis in 2011 (2 died from leptospirosis in 2010). Further analysis of island fox blood samples from 2009-2010 indicated that seroprevalence to *Leptospira* was higher in adults (79%) than in pups (6%), and adult seroprevalence increased from 2009 to 2010 (69% to 84%). Successful culture of *Leptospira* from fox and skunk urine collected in February 2011 indicated the particular Pomona serovar on Santa Rosa is one last isolated from a stranded seal in 1970(R. Zuerner, USDA, pers. Comm.; Zuerner And Alt 2009). At this time it is unknown whether Santa Rosa foxes and/or skunks are maintenance or accidental hosts for *Leptospira*.

Table 8. Island fox mortalities, Santa Rosa Island, 2011.

PIT Tag	ID	Sex	Born	Age	Died	Mortality Cause
25401	M86	M	Wild	1	2/28/2011	Unknown
21E0F	M84	M	Wild	1	6/28/2011	Unknown
A426D	F187	F	Wild	1	10/6/2011	Unknown
E1154	M53	M	Wild	3	11/14/2011	Unknown
C7B1B	F125	F	Captive	9	12/12/2011	Predation
51511	M32	M	Wild	5	12/26/2011	Unknown
05678	F185	F	Wild	1	12/31/2011	Predation

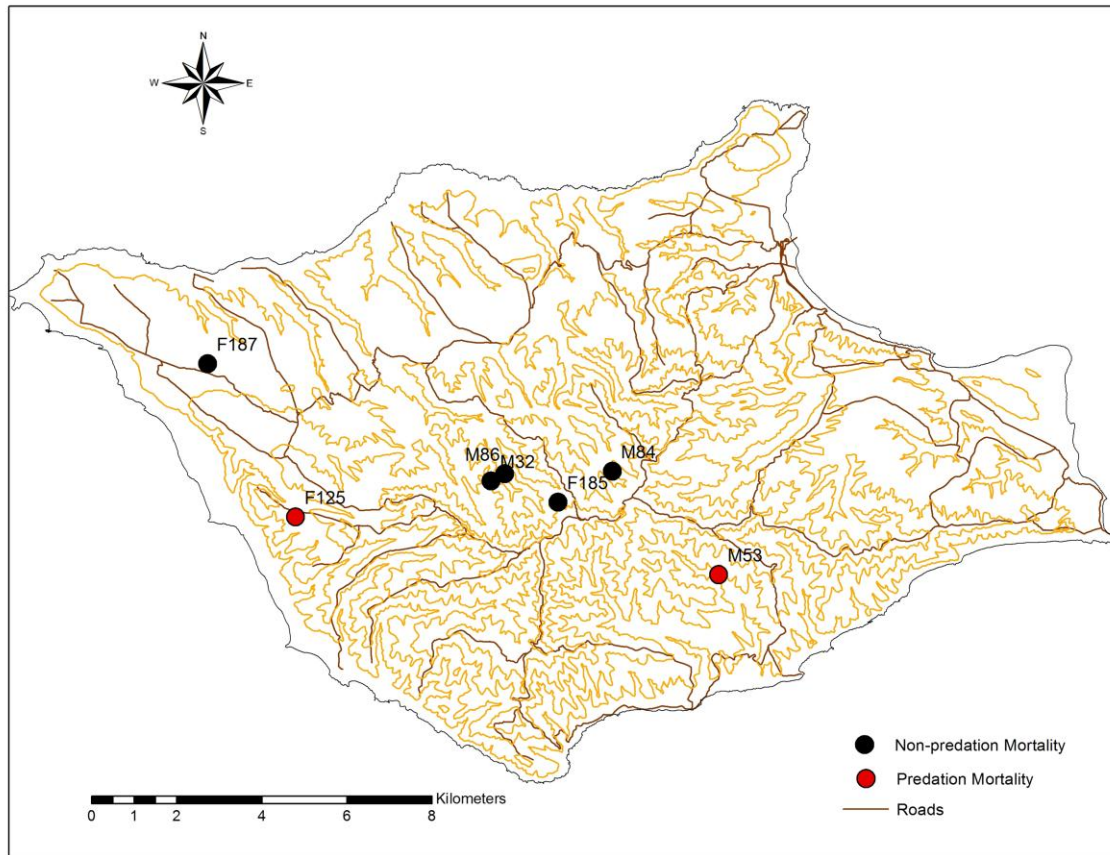


Figure 9. Location of radiocollared island fox mortalities, Santa Rosa Island, 2011.

Wild Population Monitoring

Trapping was conducted on the 18 “ladder” grids (Fig. 3) from late June through late August. Targeted trapping was conducted from August through December on 20 transects in order to vaccinate foxes and replace/add radiocollars. A total of 84 foxes (57 adults and 27 pups) were trapped on grids, and density estimates for the grids ranged from 0.2 – 2.5 foxes/km² (Table 9). There were no adult foxes caught on the Sierra Pablo, Johnson’s Lee or Carrington Point grids, so trap-nights from those grids were combined with the closest grids (Old Ranch, Lighthouse Road and Telephone Road grids, respectively) for analysis. When the average density of 1.3 foxes/km² was applied to the island area (216 km²), the estimated islandwide adult population was 280 foxes, with an 80% confidence interval of 220-340 and a coefficient of variation of 0.17 (Table 10). Including pups in the analysis resulted in an islandwide population estimate of 449 foxes (80% CI = 366-532). The sex ratio was close to even for adults and pups on the grids (Table 11), while the ratio of pups to females was low (0.93). During target trapping, 45 additional individuals were trapped, making a total of 129 foxes handled during trapping season.

Between 2010 and 2011 the island fox population on Santa Rosa increased substantially. The annual rate of increase, or lambda, was 65% for adults, and 59% for all foxes (adults and pups combined). This reflects the high survival in 2011, particularly when compared with 2010. Moreover, the fox population is still considerably lower than pre-decline levels, which were likely above 1,000 adults (Roemer et al. 1994), and so growth is not yet limited by resources.

Table 9. Adult density estimates for ladder grids, Santa Rosa Island, 2011.

Grid	Date Trapped	Indiv.	Density (foxes/km ²)	SE	CV*
Bee Canyon	6/29 – 7/4	5	1.8	1.003	0.56
Pocket Field	7/1 – 7/4	3	1.4	0.879	0.61
Arlington Springs	6/30 – 7/4	7	2.5	1.226	0.49
Burma Road	7/5 – 7/10	3	0.7	0.626	0.87
China Camp	7/5 – 7/10	8	1.4	0.879	0.61
Signal Road	7/8 – 7/11	6	1.3	0.900	0.71
Lighthouse	7/7 – 7/12	2			
Road/Johnson's Lee			0.2	0.247	1.39
Verde Canyon	7/20 – 7/25	4	1.4	0.882	0.61
Dry Canyon	7/20 – 7/25	8	1.4	0.878	0.61
Arlington Canyon	7/21 – 7/26	3	0.7	0.627	0.87
Old Ranch/Sierra Pablo	8/3 – 8/8	5	0.4	0.314	0.88
Quemada Canyon	8/3 – 8/8	8	2.1	1.117	0.52
Wreck Canyon	8/3 – 8/8	9	2.1	1.107	0.52
Trancion Canyon	8/22 – 8/27	4	0.7	0.627	0.87
Telephone	8/29 – 9/3	10	1.3	0.616	0.49
Road/Carrington Point average			1.3		

*CV = coefficient of variation

Table 10. Islandwide density and population estimates, 2010-2011, Santa Rosa Island.

	Captures	Individuals	Avg. Density	SE	N	80% CI	CV
<i>2010</i>							
Adults	112	49	0.78	0.149	169	128-210	0.19
Pups Included	131	64	1.35	0.213	292	233-351	0.15
<i>2011</i>							
Adults	128	57	1.3	0.217	280	220-340	0.17
Pups Included	168	84	2.1	0.300	449	366-532	0.15

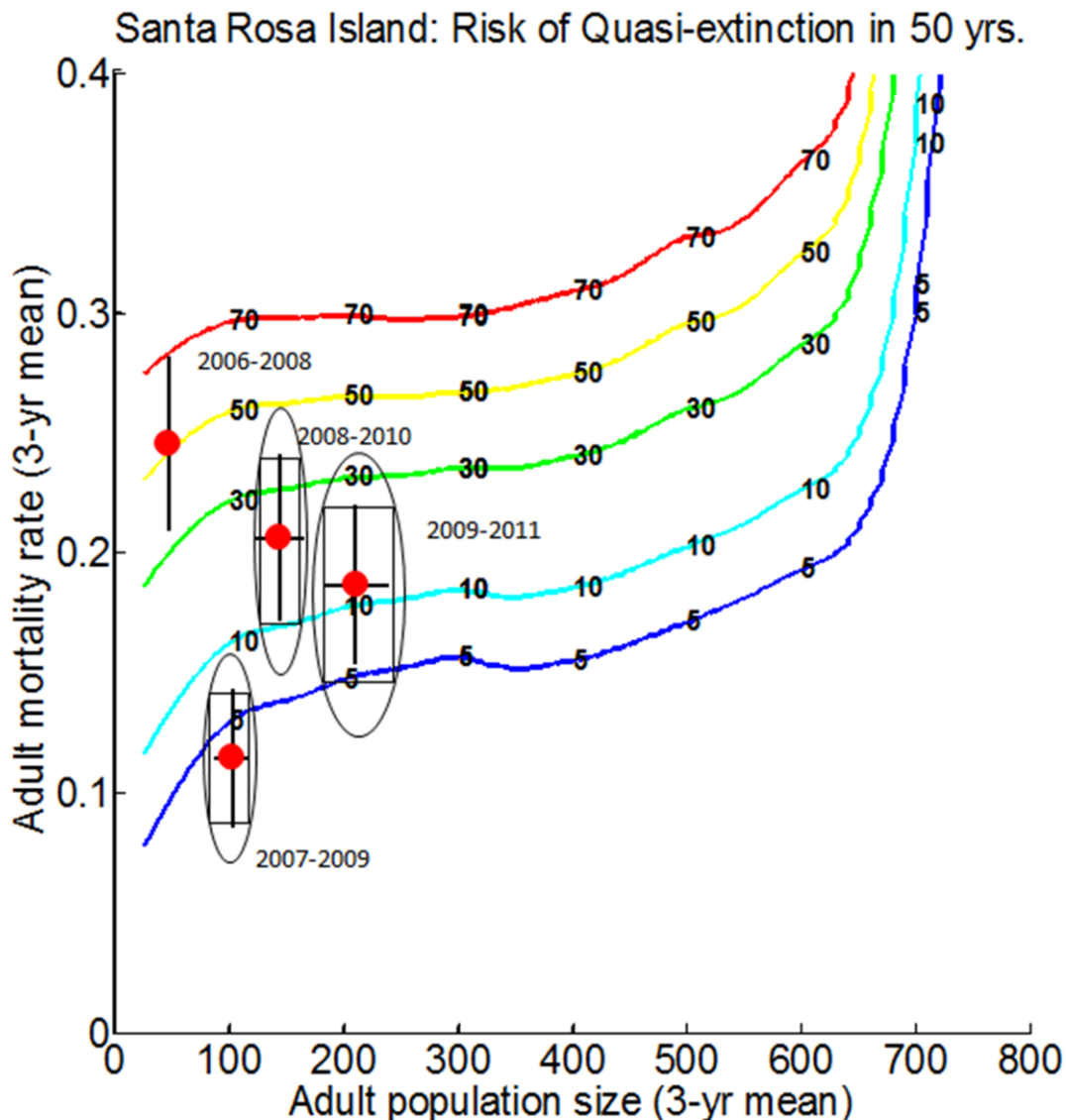


Figure 10. Extinction risk for Santa Rosa Island foxes under 2006-2011 averages for adult mortality and population size.

To determine whether the Santa Rosa population was approaching biological recovery, we plotted 3-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 isotopes 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 3-year averages for 2008, 2009, 2010 and 2011 (Fig. 10) show that the Santa Rosa subspecies, in contrast to the three other listed subspecies, still has a relatively high probability of extinction in the near to mid-term. This is due to the lower annual survival and lower population size in 2010, and underscores the importance of mounting an effective response to future predation-caused mortalities (the park now has ground-based eagle survey and capture capability, due to an

agreement with the Institute for Wildlife Studies). Survival increased in 2011 (see Fig. 4) as did island fox densities. The graph indicates that lower mortality will have a greater contribution to the probability of persistence than will higher population levels

Table 11. Number of foxes captured, by age and sex, on 18 Santa Rosa grids, 2011.

	Male	Female	Total
Pups	12	15	27
Adults	28	29	57
Total	42	44	84

Vaccination of Wild Foxes and Establishment of Sentinel Animals

After the grids were trapped, transect trapping was conducted to manage radiocollars, establish sentinel animals for disease detection, and to vaccinate wild foxes. Between transect trapping and grid trapping, 162 foxes were captured on Santa Rosa in 2010. Of those foxes, 145 (90%) were vaccinated against rabies and 107 (66%) were vaccinated against distemper. We would have vaccinated all foxes against rabies, but we did not have enough vaccinations on hand. 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. 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, Appendix A in Coonan 2010). 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). Recommendations from the health group of the Island Fox working Group are to switch to the vaccinated core strategy when a population reaches about 50% of the recovery goal. With less than 300 adults in the Santa Rosa population, we are not yet at 50% of the recovery goal. We also have a goal of leaving 10-20 collared juvenile foxes unvaccinated, to act as sentinel animals for detection of pathogen outbreaks. All foxes, except sentinels, will continue to be vaccinated against rabies, since there is no naturally occurring strain of rabies in island fox populations.

During the 2010 trapping season we continued our efforts to establish a sample of at least 10-20 unvaccinated, radiocollared sentinel animals (Table 12). Total number of sentinels established was 30 individuals. In future years we will try to maintain a sample of at least 20 such sentinels. In 2011 we added 26 radiocollared individuals, removed collars from 4 individuals, and swapped out 8 collars. Three sentinel animals died in 2011, though the carcasses were too decayed for necropsy.

Table 12. . Radiocollared foxes identified as disease sentinels on Santa Rosa Island, 2010-2011.

ID	PIT Tag	Sex	Age Class	Date Collared	Comments
M79	B0712	M	1	7/8/2010	
M80	A3039	M	1	7/12/2010	
M81	71E45	M	1	8/18/2010	
F181	F4F4E	F	0	8/18/2010	
F182	F0B62	F	0	8/18/2010	
F183	B2560	F	1	8/21/2010	
M82	95C6F	M	0	8/23/2010	
M83	A5825	M	1	9/30/2010	
F184	12843	F	1	9/30/2010	
F185	05678	F	0	10/2/2010	Died 12/31/2011 (predation)
M84	21E0F	M	0	10/2/2010	
M85	C6561	M	0	10/3/2010	Died 2/28/2011
M86	25401	M	0	10/4/2010	
F186	F1155	F	0	11/15/2010	
M87	36401	M	0	12/12/2010	
M91	4466C	M	1	6/29/2011	
F187	A426D	F	1	6/30/2011	Died 10/6/2011
F182	F0B62	F	1	8/4/2011	
M95	87821	M	0	8/6/2011	
M97	87440	M	0	8/18/2011	
M98	25E35	M	1	8/19/2011	
F189	84774	F	1	8/22/2011	
F190	05735	F	0	8/23/2011	
M99	87479	M	0	8/23/2011	
M101	45013	M	1	10/3/2011	
F192	87453	F	0	11/9/2011	
M102	04953	M	0	11/10/2011	
F193	86634	F	1	11/14/2011	
F194	87268	F	0	12/13/2011	
F195	2184D	F	1	12/14/2011	
F196	40962	F	1	12/31/2011	

Blood Samples and Serosurvey

In 2011, blood samples were collected from 186 Santa Rosa foxes. In 2011 we conducted a serostudy on island fox blood samples from both San Miguel and Santa Rosa islands. A total of 66 Santa Rosa samples were analyzed, 39 from 2009 and 28 from 2010. As per recommendations from the island fox health subgroup of the Island Fox Working Group (Appendix A in Coonan 2010), samples were tested for antibodies to canine distemper virus (CDV), canine parvovirus (CPV), canine adenovirus (CAV) and *Toxoplasma* at Cornell University's Animal Health Diagnostic Center (Dr. Edward J. Dubovi). Results (Table 6) indicate no exposure to either CDV or CPV in Santa Rosa foxes, whereas 2 of 66 samples (3%) were positive for CAV. Results for *Toxoplasma* were not available as of March, 2012. Seroprevalence to CAV was much less on Santa Rosa than on San Miguel, perhaps because transmission of that common virus is less at low densities. In the past, seroprevalence to canine adenovirus has been as high as 97% among Santa Rosa foxes (Table 7).

Density of Island Spotted Skunks

We have marked individual skunks with PIT tags since 2006. Since 2009, when we began grid trapping, we have been 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. During grid trapping in 2011 we captured 104 individual skunks. The number of individual skunks, and thus the density, varied on the 18 ladder grids (Table 12). Applying the average density of 14.7 skunks/km² to the island's area (216 km²) resulted in an islandwide density estimate of 3,166 skunks, with an 80% confidence interval of 3,678 – 3,950 and coefficient of variation of 0.14. With an islandwide estimate of 449 foxes, skunks were 7 times as abundant as foxes. Over the past three years, the skunk population has been fairly stable at about 3,000 skunks (3,013 in 2009; 2,910 in 2010).

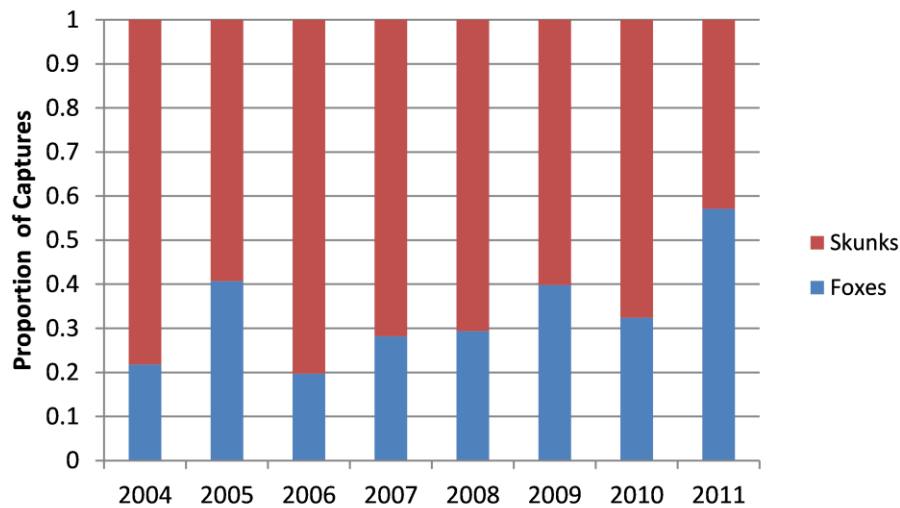
The relative number of foxes and skunks trapped during annual monitoring suggests that skunks, although still very abundant, are starting to decline as the Santa Rosa fox population recovers (Figure 14). Both the number of total captures and the number of total individuals indicate that since 2006 the relative abundance of foxes has increased, whereas that of skunks has decreased. Given the 2009-2011 skunk population estimates of about 3,000 and the apparent decline in skunks, the skunk population in previous years may have been as high as 4,000.

Table 13. Density of island spotted skunks on ladder grids, Santa Rosa Island, 2011.

Grid	Date Trapped	Indiv.	Density (skunks/km ²)	SE	CV*
Bee Canyon	6/29 – 7/4	3	7.9	5.3778	0.68
Pocket Field	7/1 – 7/4	3	7.3	5.1473	0.71
Arlington Springs	6/30 – 7/4	9	21.9	9.4402	0.43
Burma Road	7/5 – 7/10	1	2.6	3.5	1.37
China Camp	7/5 – 7/10	4	10.8	6.2562	0.58
Signal Road	7/8 – 7/11	6	14.9	7.4977	0.50
Lighthouse Road	7/7 – 7/12	8	19.9	8.8942	0.45
Verde Canyon	7/20 – 7/25	4	9.5	5.8717	0.62
Dry Canyon	7/20 – 7/25	3	7.1	5.0997	0.72
Arlington Canyon	7/21 – 7/26	4	10.3	6.1107	0.60
Old Ranch	8/3 – 8/8	2	4.3	4.1173	0.97
Sierra Pablo	8/3 – 8/8	3	7.7	5.2717	0.69
Quemada Canyon	8/3 – 8/8	6	16.0	7.803	0.49
Wreck Canyon	8/3 – 8/8	4	12.4	6.7624	0.54
Johnson's Lee	8/25 – 8/27	8	19.4	8.7512	0.45
Trancion	8/22 – 8/27	10	24.9	10.2126	0.41
Telephone Road	8/29 – 9/3	6	14.2	7.3102	0.52
Carrington Point	8/30 – 9/4	20	52.9	17.242	0.33
average			14.7		

*CV = coefficient of variation

a)



b)

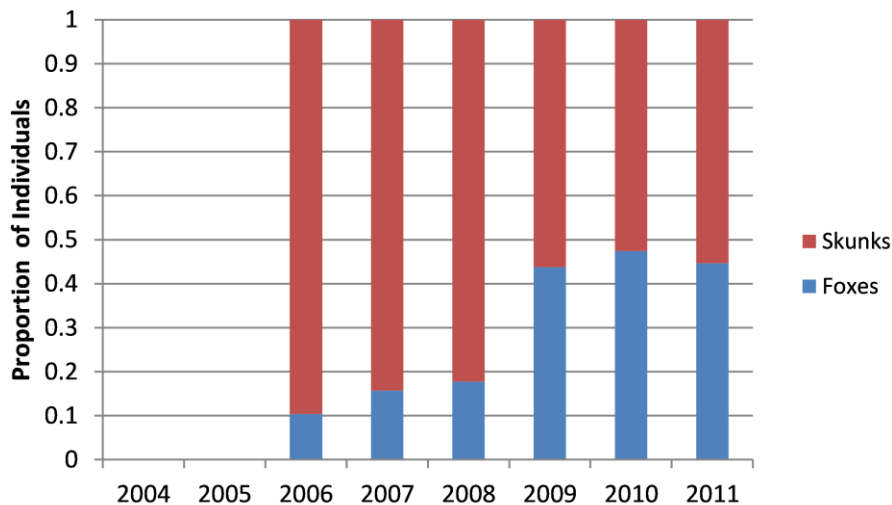


Figure 11 . Proportion of captures (a) and individuals (b) for island foxes and island spotted skunks trapped during annual population monitoring on Santa Rosa Island, 2004-2011.

Future Plans

Monitoring results from 2011 indicate a growing island fox population, with high survival, but still at only about 25% of likely historic levels. Intensive island fox monitoring will continue in 2012. We will maintain a sample of >50 radiocollared foxes on the island, and we will conduct population monitoring in summer/fall 2012, using small, “ladder” grids (Rubin et al. 2006). All newly encountered wild animals will be PIT-tagged, all captured foxes will be vaccinated against canine distemper virus and rabies, and blood samples will be drawn from a subset of the island foxes we trap. Additionally, we will test blood samples for evidence of exposure to *Leptospira*. We will also attempt to culture *Leptospira* from island fox and skunk urine samples obtained by cystocentesis, a sterile technique which involves using a syringe to collect urine from the bladder.

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