**National Park Service**
**U.S. Department of the Interior**

**Natural Resource Stewardship and Science**

# Island Fox Recovery Program

*Channel Islands National Park 2013 Annual Report*

Natural Resource Report NPS/MEDN/NRR—2014/845

**ON THE COVER**
Female island fox 86401, San Miguel Island, 1994
Photograph by National Park Service

# Island Fox Recovery Program

*Channel Islands National Park 2013 Annual Report*

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# Executive Summary

In 2013 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 (*U. l. santarosae*). Results from annual monitoring indicate that both populations have generally increased over time and have high annual survival. The San Miguel subspecies returned to pre-decline population levels in 2011, and may have reached carrying capacity. It can be considered biologically recovered. The Santa Rosa subspecies is currently at about 2/3 of its likely pre-decline level.

Both subspecies, as well as Santa Cruz Island foxes (*U. l. santacruzae*), were the object of intense recovery actions from 1999-2008, the primary actions being relocation of predatory golden eagles (*Aquila chrysaetos*) and captive breeding and reintroduction of island foxes. From 1999-2006, 44 golden eagles were trapped on the islands and relocated to northern California, with a resultant increase in island fox survival. A 10-year program of captive breeding and release of all three island fox subspecies was completed in 2008. During that period, in which captive breeding was conducted separately on each island, 225 pups were born in captivity, and 254 foxes were released to the wild. 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 had been almost completely mitigated during the 10-year time period, and wild island fox survival rose to 80-90% on all 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. Fox population status and trend is monitored via estimation of density and population size using capture-mark-recapture data from small grid trapping. Survival and mortality factors are monitored via radiotelemetry. Excellent survival and reproduction in the wild have allowed rapid growth of the small, recovering populations, and by the end of 2013 the San Miguel island fox population estimate was 551 adults (Fig. 1) and 577 total foxes, numbers which are greater than population estimates prior to the predation-caused decline of the1990s. The San Miguel population may have approached carrying capacity. The total number of foxes has hovered around 550 since 2010. In 2013 the Santa Rosa population estimate was 732 adults and 894 total foxes, numbers which may represent about 50% of pre-decline numbers, and of carrying capacity.

Annual survival of foxes on San Miguel declined to about 80% in 2013, likely due to density-dependent effects, continued drought, and the appearance of a novel acanthocephalan parasite. Twelve radiocollared foxes died on San Miguel in 2013, one from eagle predation, and 5 of the mortalities had evidence of heavy infestation by an unidentified acanthocephalan parasite, along with emaciation and enteritis (inflammation of the small intestine). Annual survival on Santa Rosa was 94% in 2013, and only 3 radiocollared foxes died, all from unknown causes.

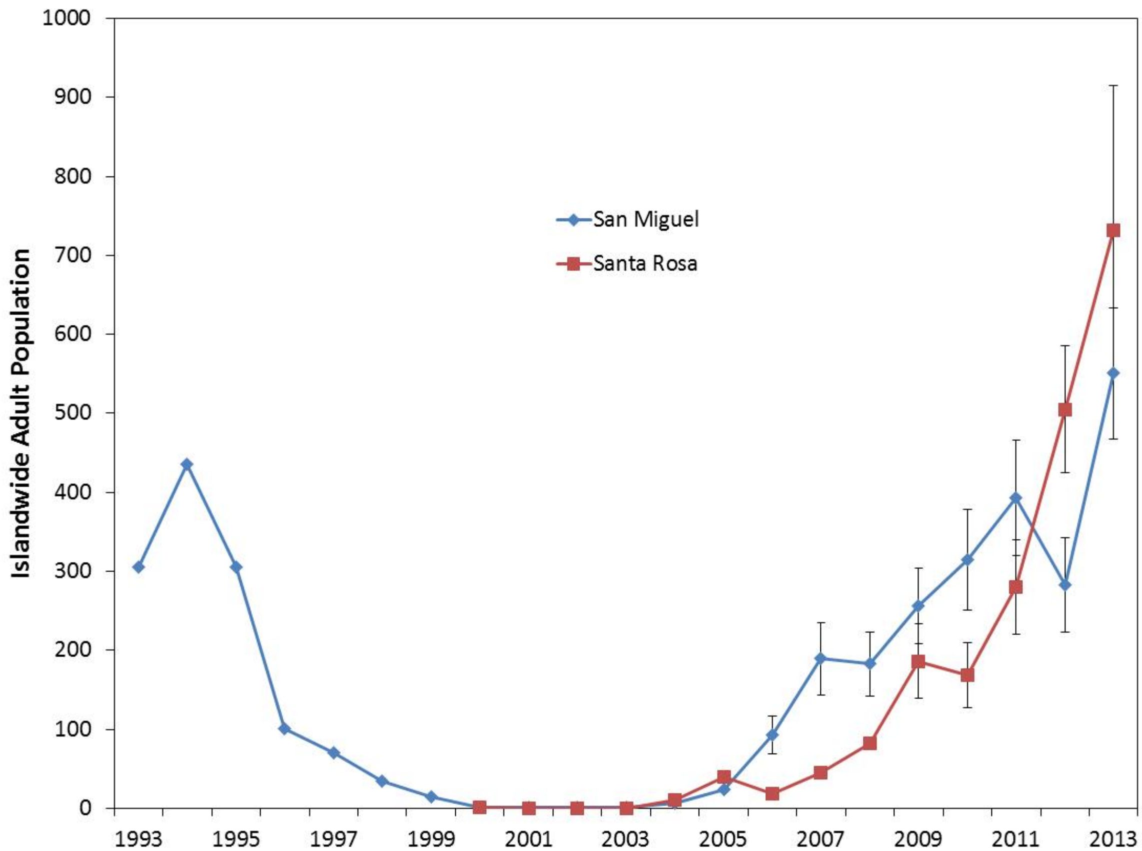


Figure 1. Annual estimated number of adult island foxes for San Miguel and Santa Rosa. Pre-decline estimates are not available for Santa Rosa; 80% confidence intervals are shown for estimates from program Density (estimates from 1993-1998 are from program Capture.

Reproduction was extremely low on San Miguel, where only three pups were caught on the monitoring grids (32 were caught in 2012). A total of 25 pups were caught on Santa Rosa monitoring grids in 2013.

Data on fox weights and body condition scores support the conclusion that island foxes on San Miguel Island have reached carrying capacity, while those on Santa Rosa have not. Adult weights on San Miguel in 2013 were lower than in other years, as were pup weights, whereas those on Santa Rosa were not, and have actually increased in recent years. San Miguel also had proportionately more foxes in the "thin" body condition category, and Santa Rosa had proportionately more in the "optimal" category.

The higher mortality, lower reproductive effort, and lower weights are perhaps to be expected as the San Miguel population adjusts to the resource limits of carrying capacity. Food resources may also be lower due to the prolonged drought in southern California. Deer mouse (*Peromyscus maniculatus*) populations have been very low since early 2012. All the same, the appearance of the acanthocephalan parasite is worrisome. The high mortality on San Miguel continued in 2014, with 7 additional radiocollared mortalities occurring in January-March of 2014. Two of those mortalities had massive infestation by acanthocephalans, emaciation, and enteritis, and those foxes also occurred in the Tyler

Bight area, where the previous acanthocephalan cases have occurred. We are awaiting identification of the parasite to species, at which point we will know the likely intermediate host. That information, in turn, will allow the Fox Health Group of the Island Fox Conservation Working Group to formulate a plan for further investigation, and possible intervention, if warranted.

As in previous years, 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 15.8 skunks/km$^2$ and an islandwide estimate of 3,404 skunks, substantially lower than the previous year’s estimate of 4,282 skunks. The estimate includes both adults and juveniles, which were not distinguished from each other in the field. Skunks were almost 4 times as abundant as island foxes, in terms of estimated density. However, skunk density estimates may be biased high because of the low number of skunk recaptures. Skunks may finally be declining from the population highs reached during fox decline. This was the first year in which the number of individual skunks captured on the grids (129) was lower than the number of foxes (152).

About 45% of trapped foxes were vaccinated against canine distemper virus (CDV), and 60% against canine distemper virus (CDV). Number of vaccinates for rabies was 113 on San Miguel and 166 on Santa Rosa, while the number of foxes vaccinated against CDV was 107 on San Miguel and 109 on Santa Rosa. 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). While we do not have a geographic core, we do maintain a demographic core of 80-100 foxes vaccinated against CDV. Such a core could be used as the nucleus of a captive breeding program, should one be required after an outbreak of CDV on an island. Limiting the number of foxes vaccinated against CDV also allows the circulation of the native, CDV-like morbillivirus present in island fox populations. That native virus likely confers some immunity against CDV.

## 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 2013 comprised two of this report's authors (AH and RS), Andy Abate, and a number of volunteers: Monique Ambrose, Stacy Baker, Mark Heully, Rebecca Kelley, Julie King, Nathan Melling, Seth Newsome, Jessica Sanchez, Carl Schwartz, Nick Smith, Desiree Thomaier, and Madeline Tiee. The Santa Barbara Zoo continues to support our program by generously offering their staff for volunteer work on the islands. Zoo personnel who volunteered in the fox program for us included Liz Baily, Ria Boner, Jill Cunningham, Dailee Fagnant and Summer Gentry. Thanks to Rich Block and Sheri Horiszny for making this collaboration possible.

We thank Dave Dewey for conducting aerial radiotelemetry of collared foxes.

We appreciate the support of our partners at the Institute for Wildlife Studies: Dave Garcelon, Brian Hudgens, Pete Sharpe, Don Jones and Kim Smith; they remain a constant source of assistance and inspiration in our monitoring and conservation efforts. We continue to work closely with our neighbor, The Nature Conservancy, on Santa Cruz Island, and we appreciate our close relationship with Christie Boser of their staff.

Thanks to Cindy Stirner 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 dispatcher 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.

This report was improved by the review and suggested revisions provided by Stacey Osterman-Kelm.

# 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, Coonan et al. 2010).

Dramatic fox population declines on San Miguel and Santa Cruz Islands were detected during the 1990s (Coonan et al. 2010). The island fox population on San Miguel declined from an estimated 450 adults in 1994 to 15 in 1999 (Coonan et al. 2005b). 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 also the cause of 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, capture and relocation 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 (Coonan et al. 2010).

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 (Coonan et al. 2010).

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 islands foxes. In 2005-2006 the Park and The Nature Conservancy cooperated to remove feral pigs (>5,000 total) from Santa Cruz Island, thereby eliminating that non-native golden eagle prey source.  Elk (*Cervus elaphus*) and mule deer were removed from Santa Rosa Island by 2014. 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 2014 there were >40 bald eagles on the northern Channel Islands, with breeding occurring on Anacapa, Santa Cruz and Santa Rosa Islands.

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 adult populations that number in the hundreds on San Miguel and Santa Rosa islands and over 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 and elk from Santa Rosa Island, now largely complete, has eliminated the last of the non-native prey base from the northern Channel Islands.

A draft island fox recovery plan was recently released to the public (US Fish and Wildlife Service 2012) and a final recovery plan will likely be published in 2014. The plan recognized the recovery actions that have brought the listed subspecies to the brink of recovery: captive breeding and reintroduction of foxes to the wild, and monitoring and relocation of golden eagles. The plan requires that monitoring and mitigation plans be developed for both eagle predation and disease, before listed island fox subspecies may be delisted. The plan set demographic goals, combinations of survival and population size, which would guarantee persistence of island foxes into the foreseeable future. Three of the four listed island fox subspecies reached these levels in 2013 (Coonan 2013, this report).

## 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 is being 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 to 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.

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. The process of developing island fox recovery criteria based on demographic modeling was described by 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, described in what is 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 (Coonan et al. 1998). 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 identity 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 2013. The recovery actions, which included island fox population and mortality monitoring, were conducted under U.S. Fish and Wildlife Service Recovery Permit TE86267, 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 2013 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 (similar monitoring on neighboring Santa Cruz Island, also within the park, is conducted by The Nature Conservancy). 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

Table 1. Descriptions of body condition scores used to rate captured foxes.

| Score | Condition | Description |
|---|---|---|
| 1 | Emaciated | Ribs and lumbar vertebrae easily seen, pelvic bones and all other bony structures obvious and prominent. Tail base prominent and bony. Accentuated concave abdominal tuck. Accentuated, severe hourglass shape to waist. No discernible body fat. Obvious loss of muscle mass. |
| 2 | Thin | Ribs and lumbar vertebrae easily seen with no fat cover. Pelvic bones obvious. Tail base bony with little soft tissue. Marked concave abdominal tuck. Marked hourglass shape to waist when viewed from above. |
| 3 | Optimal | Ribs, lumbar vertebrae, pelvic bones and other bony structures easily felt with slight fat cover. Tail base smooth with thin, soft tissue cover. Concave abdominal tuck. Smooth hourglass shape to waist. |
| 4 | Fat | Ribs, pelvic bones and lumbar vertebrae are difficult to feel. Tail base has fat deposition with moderate soft tissue cover. Concave tuck is decreased to absent. Loss of hourglass shape to waist with back slightly broadened. |
| 5 | Obese | Ribs and lumbar vertebrae are very difficult to impossible to feel. Pelvic bones are difficult to palpate with thick tissue cover. Tail base is thickened from fat deposition with thick soft tissue cover. Abdomen is convex with or without a pendulous ventral bulge. Back is markedly broadened. |

# Methods

## Population Monitoring of Foxes and Skunks

Grid trapping to estimate density was conducted July – August on Santa Rosa and September - October on San Miguel. On both islands, transect trapping to manage collars, establish sentinels and administer vaccines was conducted from July 2013 through January 2014. For both grid and transect trapping, 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 shadecloth 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 assigned a body score of 1-5 (Table 1). 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, 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. Other biological samples collected included scat, whiskers, and urine (the latter via cystocentesis).

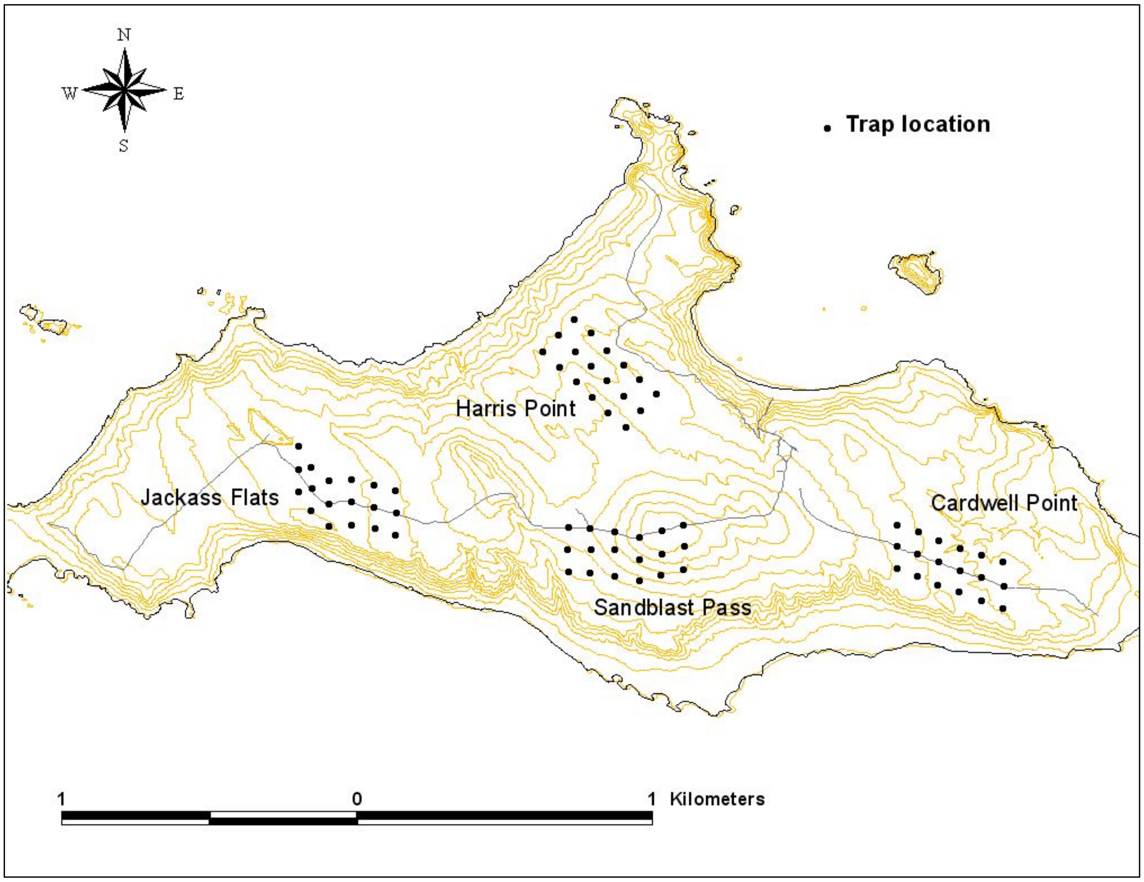


Figure 2. Location of trapping grids, San Miguel Island.

Island spotted skunks occur on Santa Rosa Island (but not on San Miguel) and so were caught in traps set for island fox monitoring. Captured skunks were restrained, with great care, and then weighed, sexed, and marked with PIT tags.

Grid trapping data was used to estimate the distribution and demography of island foxes, through such measures as density, 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. We assume the grids are representative of the island . 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).

For each grid, one line of traps was dispersed along the trail, with another line of traps directly north and south of each trap-point on the trail, with 250 m grid spacing. The grids were designed to be relatively easy to set up and trap, so that a 1-2-person crew could trap one grid per week while still performing other duties (such as monitoring radiocollared foxes).  Grids were run for 5 nights.

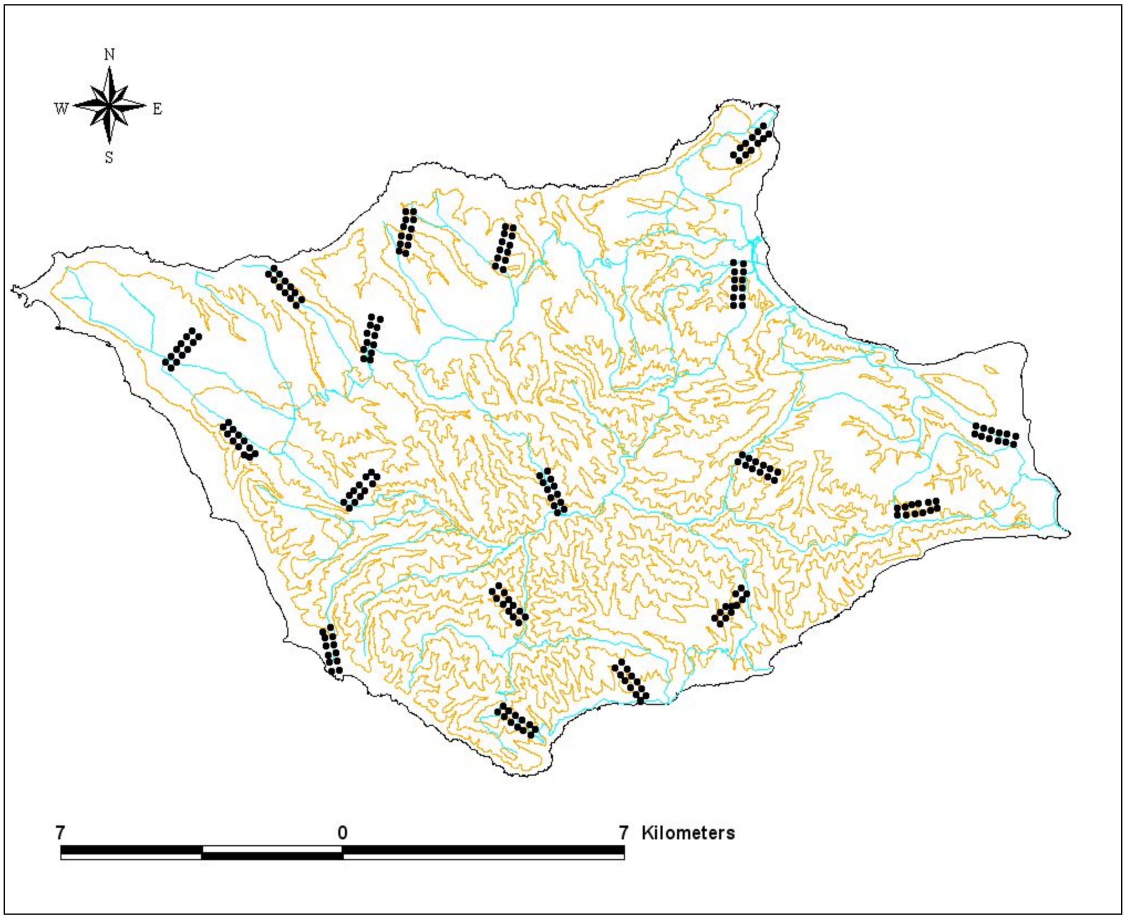


Figure 3. Location of trapping grids, Santa Rosa Island.

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 switched to grid monitoring, and established 18 “ladder” grids (Fig. 3), each comprising a 2 by 6 trap array with 250 m trap spacing, 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 (g0), and spatial scale or movement ($\sigma$) parameters. We used the maximum likelihood estimator and considered each grid to be a separate trapping session, with density varying by trapping session, but g0 and $\sigma$ assumed to be constant across sessions. 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).

Because we marked skunks on Santa Rosa with PIT tags, we were able to estimate skunk density and islandwide population size in the same manner as for island foxes.

## Survival and Mortality Causes

On both islands, mortality-sensing radio-telemetry collars (Holohil Systems Ltd., Ontario, Canada) were placed on at least 50 captured foxes in order to assess mortality rates and factors. The sample of foxes was chosen to be representative aof sex and age structure in the population. 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, Montana State University, and D. Doak, University of Colorado, pers. comm.).

For both subspecies we used the islandwide 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 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 Montana State 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 2013 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 2013 we affixed radiocollars to a number of unvaccinated juvenile foxes for this purpose.

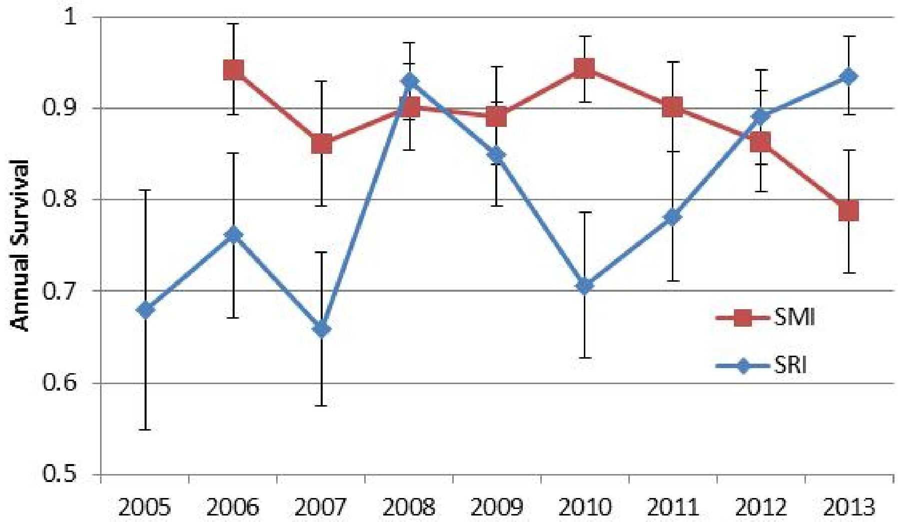


Figure 4. Annual survival for island foxes, with 80% confidence intervals, San Miguel and Santa Rosa islands.

# Results and Discussion

## San Miguel Island

### *Mortality Monitoring*

Throughout 2013 we maintained a sample of 41-53 radiocollared foxes on San Miguel, and by the end of the year there were 46 radiocollared foxes being monitored. Annual survival for San Miguel island foxes in 2013 was 79% (80% CI = 72-85%), marking the first year since reintroductions began in 2004 that annual survival on San Miguel has fallen below 80% (Fig. 4). Twelve radiocollared foxes died in 2013, one from golden eagle predation (Table 2). The relatively high mortality continued into early 2014, with 7 collared San Miguel foxes dying in January-March of 2014. Several of those individuals made significant movements away from their typical use areas, as if they were foraging farther afield for food, attempting to establish new territories or acquire mates.

Some of the high mortality may be due to density-dependent effects of extended drought. Precipitation records from nearby Santa Rosa Island indicate that 2013 was one of the driest on record since 1991, and followed a below-average total for the previous year. Island fox densities on San Miguel are the highest ever recorded, and there may be stiff competition for food resources, which are scarce. The park's deer mouse (*Peromyscus maniculatus)* monitoring program detected low numbers of mice in both 2012 and 2013, and many fox carcasses were found to be emaciated (Table 2).

Another factor in San Miguel island fox mortality is the appearance of acanthocephalans, a parasite that has not been recorded in island foxes before. Also called spiny-headed worms, they are endoparasites which require two hosts. Juvenile acanthocephalans are parasitic within insects or crustaceans, while the adults are parasitic in vertebrates, where they encyst in the intestinal wall and can cause intestinal perforation and peritonitis. Acanthocephalans (*Profilicolis* spp.) are known to cause mortalities in sea otters (*Enhydra lutris*).

Five of the 10 mortalities in 2013 had infection by an as-yet unidentified acanthocephalan, and all cases were clustered around the Tyler Bight area, suggesting a coastal origin (Figure 5). Two of the five island fox carcasses (M303, M267) had massive or large numbers of acanthocephalans in the intestines. Four of the 5 cases were associated with emaciation and enteritis (inflammation of the small intestine) and one (F366) had severe peritonitis, which was likely the cause of death. Of the 7 mortalities that occurred in January-March 2014, two had massive infection by acanthocephalans, emaciation, and enteritis.

The Island Fox Health Group, a subset of the Island Fox Conservation Working Group, considered the acanthocephalan cases on San Miguel at the 2013 working group meeting, and recommended further investigation (Coonan 2013). First, the acanthocephalan needs to be identified to species via molecular methods. Specimens have been tentatively identified as *Oncicola*, a species infecting lizards. If molecular methods confirm the identification, surveys may be needed to determine if the parasite occurs in either of the two lizard species on San Miguel (alligator lizard *Elgaria multicarinata* and western fence lizard *Sceloporus occidentalis*). Island fox fecal samples have been collected for fecal floatation tests to determine if foxes are actively shedding eggs of the parasite. The Health Group did not think the current impact on foxes warranted treatment with anthelminthics, though that may be a possibility if a significant number of additional mortalities occurs.

Table 2. Mortalities of radiocollared island foxes on San Miguel Island, 2013.

| PIT Tag | ID | Sex | Born | Age | Died | Mortality Cause |
|---|---|---|---|---|---|---|
| 88319 | F371 | F | Wild | 1 | 01/12/13 | Unknown |
| 55C2F | M257 | M | Wild | 4 | 02/11/13 | Enteritis, colitis, emaciation; Acanthocephalans,*Spirocerca* |
| 71837 | F380 | F | Wild | 0 | 02/15/13 | Predation |
| 26421 | M300 | M | Wild | 1 | 02/22/13 | Enteritis, colitis, emaciation; Acanthocephalans, *Spirocerca* |
| B7D4D | F366 | F | Wild | 1 | 02/24/13 | Enteritis, colitis, emaciation, severe peritonitis, Acanthocephalans, *Spirocerca* |
| E677F | M252 | M | Wild | 3 | 02/27/13 | Unknown (dessicated) |
| D4845 | F340 | F | Wild | 3 | 04/20/13 | Unknown (dessicated) |
| A2719 | M297 | M | Wild | 5 | 5/25/2013 | Cystitis (urinary blockage) led to septicimia. Acanthocephalans and *Spirocerca* |
| 86128 | M271 | M | Wild | 4 | 9/17/2013 | Unknown |
| 25A63 | F310 | F | Wild | 8 | 11/29/2013 | Unknown; necropsy pending |
| 58227 | M303 | M | Wild | 0 | 12/11/2013 | Enteritis, emaciation, Acanthocephalans |
| 07104 | F362 | F | Wild | 3 | 12/31/2013 | Unknown (dessicated) |

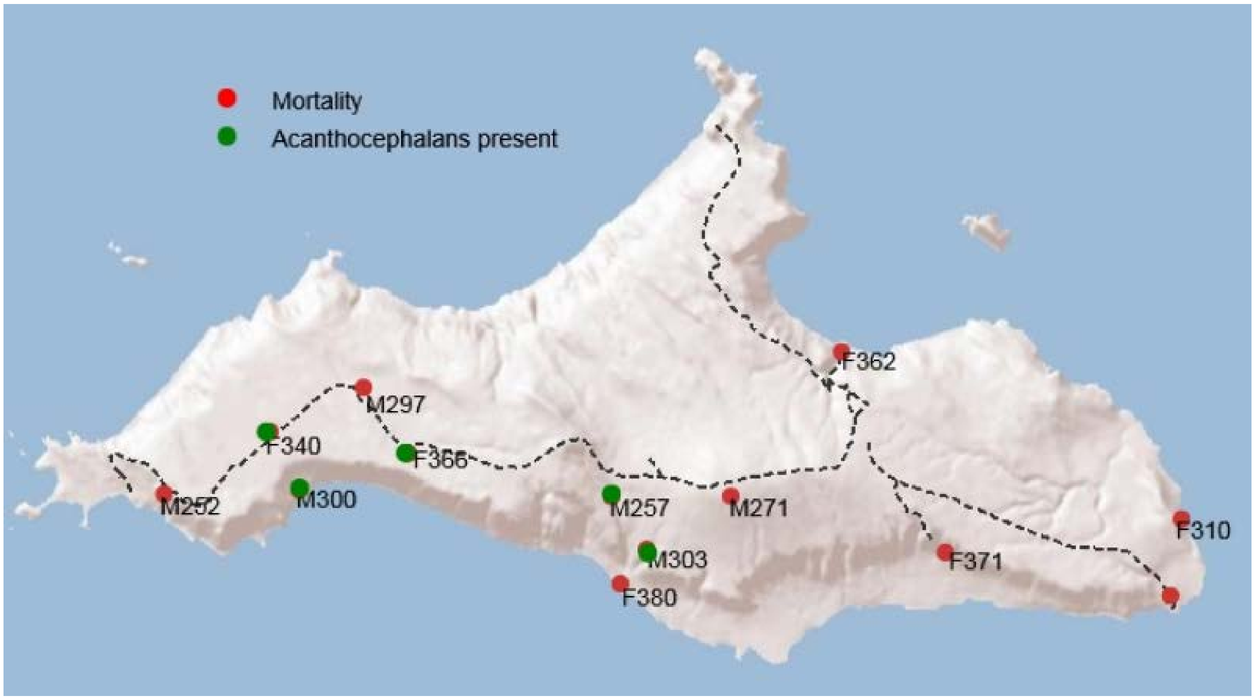


Figure 5. Locations of radiocollared island fox mortalities in 2013, San Miguel Island. Carcasses with acanthocephalans are marked in green.

### *Wild Population Monitoring*

Table 3. Adult density estimates for small grids, San Miguel Island, 2013.

| Grid* | Date Trapped | Individ. | Density (foxes/km$^{2}$) | SE | CV** |
|---|---|---|---|---|---|
| SAND | 9/18-22 | 23 | 15.3 | 3.434 | 0.23 |
| CHAR | 9/19-23 | 16 | 10.8 | 2.869 | 0.26 |
| CARD | 10/2-6 | 30 | 20.6 | 4.115 | 0.20 |
| JACK | 10/9-13 | 15 | 10.5 | 2.874 | 0.28 |
| average | | | 14.3 | | 0.12 |

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

** Coefficient of Variation = standard deviation/mean

On San Miguel grids in 2013 we captured 87 foxes a total of 157 times, with an additional 84 foxes caught on transects a total of 183 times. Three pups and 84 adults were trapped on the 4 small grids. Adult density ranged from 10-20 foxes/km$^2$, with an average density of 14.3 foxes/km$^2$ (Table 3). The coefficient of variation for the islandwide density estimate was 0.12 (a CV < 0.20 is desirable [M. Efford, Landcare Research, pers. comm.]). Multiplying the average density by the area of the island (38.1 km$^2$) yielded a population estimate of 551 adult foxes, with 80% CI = 468-634 adult foxes. This represents an approximately 95% increase from the 2012 estimate of 293 foxes (Fig. 6). When pups were included in density estimates, the islandwide population estimate was 577 foxes, with 80% CI = 491-662 (Table 4).

Table 4. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2006-2013; program Density) and from transect trapping (2005, MNKA), San Miguel Island.

| | Adults | | | | | Total (adults plus pups) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | n | N | SE | 80% CI | λ | n | N | SE | 80% CI | λ |
| 2005 | | 30 | | | | | 40 | | | |
| 2006 | 19 | 93 | 18.58 | 70-117 | 3.1 | 39 | 201 | 32.32 | 160-243 | 5.02 |
| 2007 | 37 | 190 | 35.85 | 144-235 | 2.04 | 60 | 297 | 43.93 | 241-354 | 1.48 |
| 2008 | 44 | 183 | 31.51 | 143-223 | 0.96 | 75 | 282 | 51.83 | 215-348 | 0.95 |
| 2009 | 58 | 256 | 37.80 | 208-305 | 1.39 | 79 | 318 | 39.66 | 267-369 | 1.13 |
| 2010 | 47 | 315 | 49.77 | 252-379 | 1.23 | 79 | 516 | 62.08 | 437-595 | 1.62 |
| 2011 | 56 | 393 | 57.52 | 320-467 | 1.24 | 82 | 581 | 69.10 | 493-670 | 1.12 |
| 2012 | 44 | 283 | 46.38 | 224-342 | 0.72 | 76 | 538 | 65.79 | 454-622 | 0.93 |
| 2013 | 84 | 551 | 64.89 | 468-634 | 1.95 | 87 | 577 | 66.84 | 491-662 | 1.07 |

Table 5. Adult, pup and total captures on monitoring grids, San Miguel Island, 2009-2012.

| | Adult Captures | Pup Captures | Total Captures |
|---|---|---|---|
| 2009 | 113 | 60 | 173 |
| 2010 | 89 | 64 | 153 |
| 2011 | 95 | 47 | 142 |
| 2012 | 78 | 55 | 133 |
| 2013 | 154 | 3 | 157 |

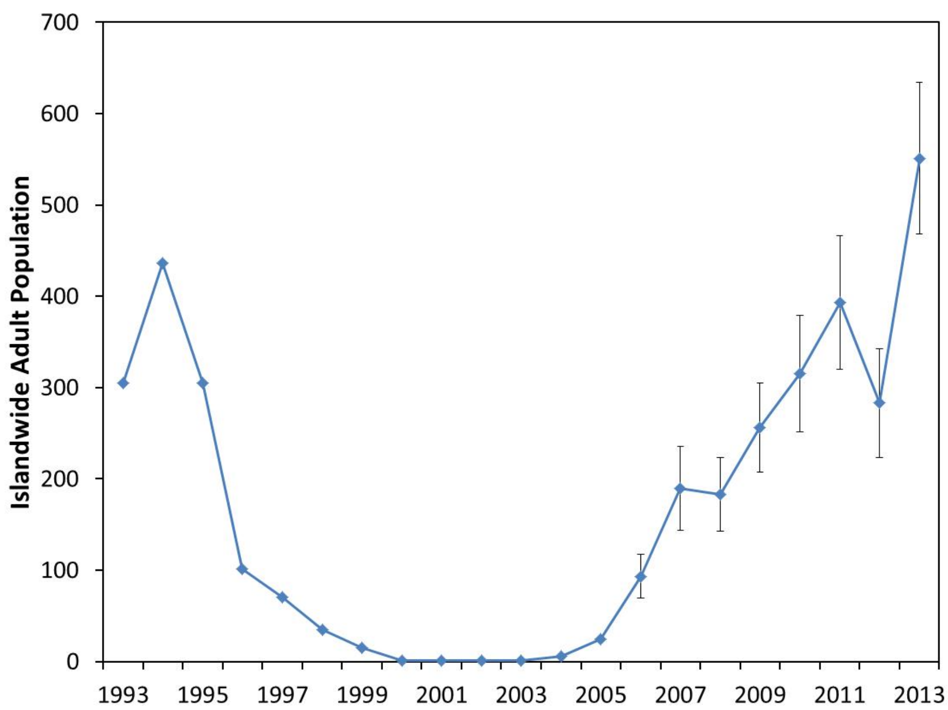


Figure 6. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2013).

Very few pups were caught on the grids (Tables 5 and 6, Figs. 7 and 8). Only 3 were caught this year, compared to 32 in 2012. At the same time, there was very high apparent survival of last year's pups, as evident in the large number of age class 1 foxes. Reproductive effort, as indicated by the ratio of pups produced per adult female, was the lowest ever recorded (Fig. 7). The low reproductive effort coupled with declining survival (Fig. 4) suggest that the San Miguel subspecies has reached carrying capacity. The number of total (adult and pup) foxes caught on the grids has not changed substantially since 2009 (Fig. 8), suggesting that carrying capacity may have been reached about then. This is also supported by the trend in estimated total islandwide population over time (Fig. 10). The total population has been hovering around a value of about 550 foxes since 2010.

A tally of captured foxes by sex and age indicated a bias toward males in adults (Table 6).

Table 6. Number of foxes captured, by age and sex on 4 grids on San Miguel, 2011.

| | Male | Female | Total |
|---|---|---|---|
| Pups | 2 | 1 | 3 |
| Adults | 48 | 36 | 84 |
| Total | 50 | 37 | 87 |

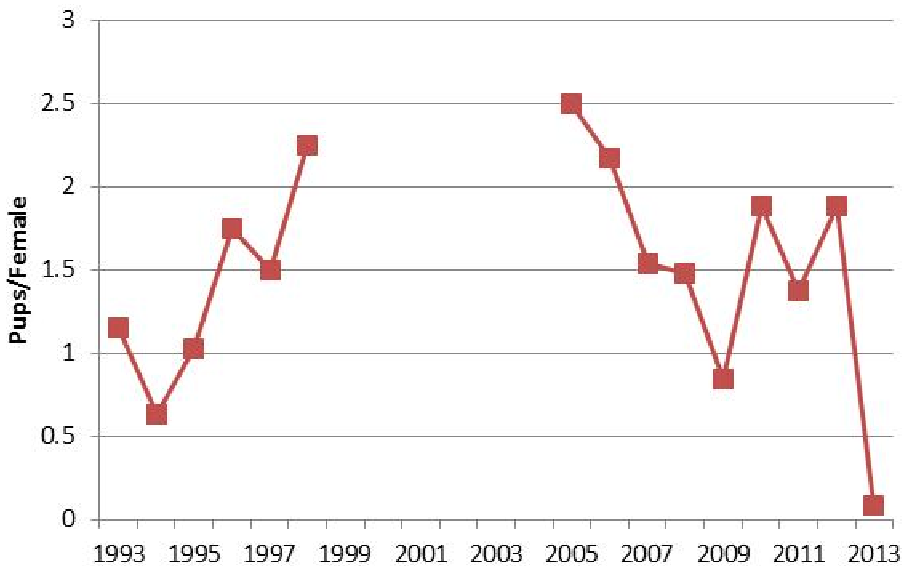


Figure 7. Reproductive effort as estimated by the ratio of pups to adult females, San Miguel Island, 1993-2013.

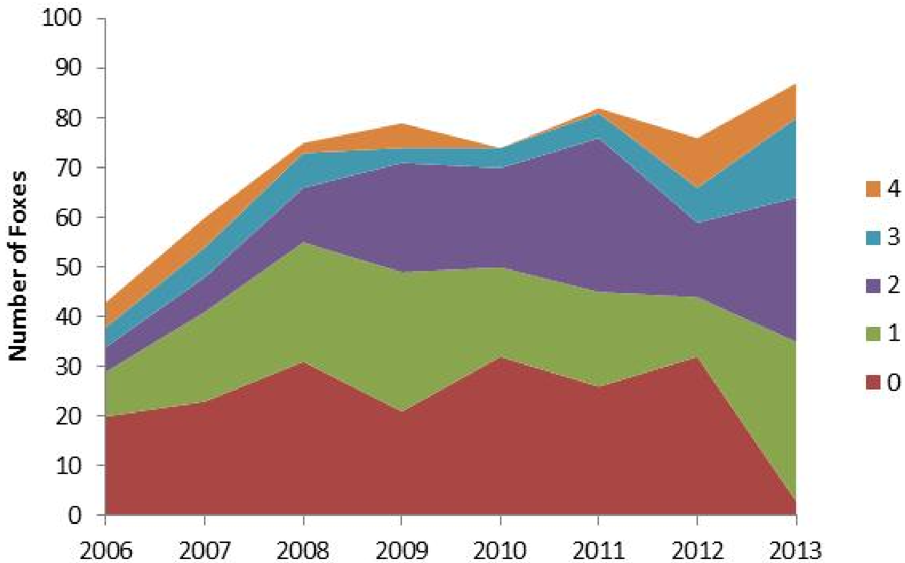


Figure  8. Total number and age class of individuals trapped on 4 grids, San Miguel Island, 2006-2013.

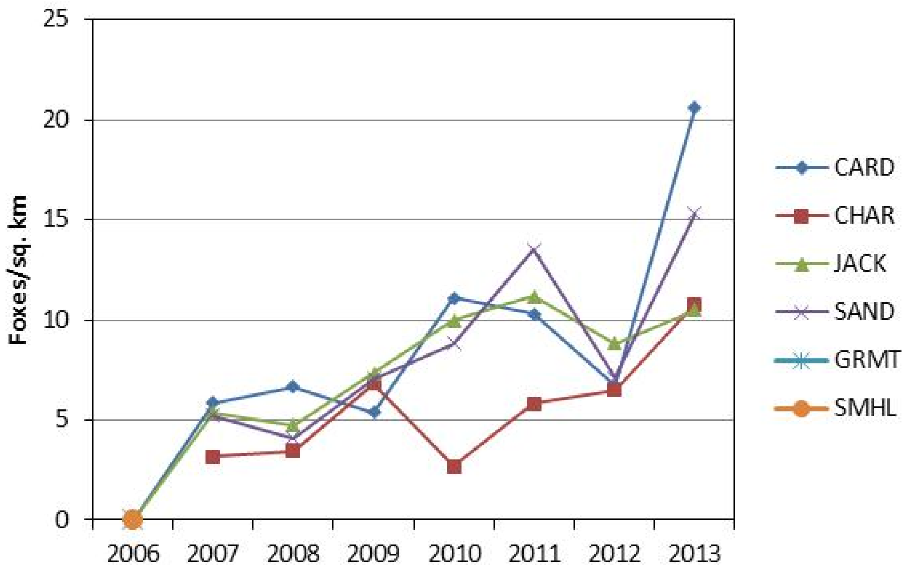


Figure 9. Individual grid densities, San Miguel Island, 2006-2013.

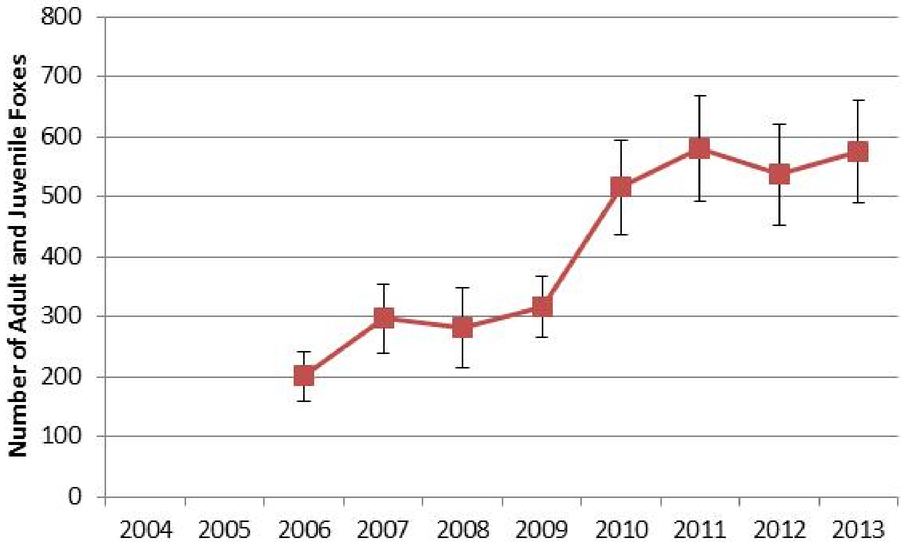


Figure 10. Estimated total (adult and pups) islandwide population, San Miguel Island.

Plots of recent values of population size and mortality rate against isoclines of extinction risk indicate that the San Miguel subspecies is recovered. . The plots of 3-year averages for 2008-2013 (Fig. 11) show that the 80% confidence limits for both mortality and population size fell below the 5% isocline, which is the acceptable level of risk identified in the USFWS draft island fox recovery plan (USFWS 2012). The San Miguel population reached biological recovery in 2008, and the values for 2009-2013 indicate even greater probability of avoiding extinction. The San Miguel subspecies has returned to pre-decline population levels, and now has five “bubbles” below the 5% extinction isocline, and so can be considered biologically recovered.

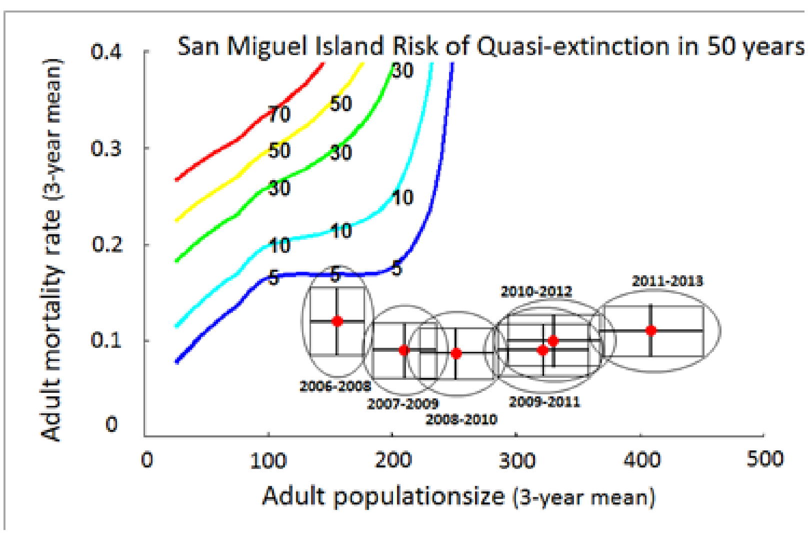


Figure 11. Extinction risk for San Miguel island foxes under 2006-2013 averages for adult mortality and population size.

Figure 12. Average annual weights for adult island foxes on a) San Miguel and b) Santa Rosa Islands.

### *Weights and Body Condition*

Evaluation of weights and body condition indices for island foxes on San Miguel and Santa Rosa Islands supports the conclusion that San Miguel island foxes are at carrying capacity and currently limited by resources. Adult weights on San Miguel in 2013 were very low (Fig. 12a). Average female weight (2.04 kg) was the lowest since weights were first recorded in 2007, and average adult male weight (2.21 kg) tied two previous lows. In contrast, adult weights on Santa Rosa, where foxes exist at much lower densities, were not low in 2013 (Fig. 12b). Male and female adult weights on Santa Rosa have increased annually since 2010.

Figure 13. Average monthly pup weights for 2007-2012 compared to those in 2013 for a) San Miguel and b) Santa Rosa Islands. Low number of samples (given in parentheses) prevented construction of confidence intervals for 2103 weights on San Miguel.

Pup weights also suggest more food stress on San Miguel. Pup weights increase over the trapping season, and 2013 weights seem lower than monthly averages from 2007-2012 (Fig. 13a), though low sample numbers prevent statistical comparisons. Pup weights from Santa Rosa in 2013 were not statistically lower than 2007-2012 monthly averages, except for July (Fig. 13b).

For those adult foxes caught both in 2012 and in 2013, we were able to investigate relative weight gain or loss between the 2 years. On San Miguel, 22 of 35 foxes (63%) lost weight between years, and the average loss was 0.2 kg. On Santa Rosa, only 18 of 56 foxes (32%) lost weight between 2012 and 2013.

Finally, body condition index values also suggest that San Miguel Island foxes were in poorer condition in 2013 than were foxes on Santa Rosa. San Miguel had relatively more foxes in Body Condition 2 (Thin) than did Santa Rosa, and the converse was also the case; Santa Rosa had a higher proportion of foxes in Body Condition 3 (Optimal) (Fig. 14). Santa Rosa had no foxes scored as Emaciated (Body Condition 1), whereas 3 San Miguel foxes were scored as Emaciated.

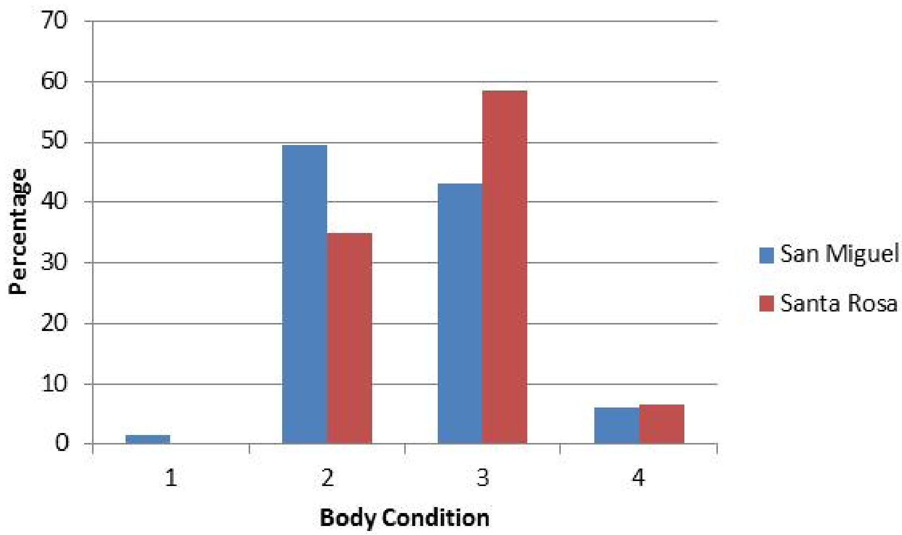


Figure 14. Percentage of foxes in four body condition index categories on San Miguel and Santa Rosa Islands, 2013.

### *Vaccination of Wild Foxes, Establishment of Sentinel Animals and Collection of Blood Samples*

After the grids were trapped, transect trapping was conducted to complete affixing radiocollars, establish sentinel animals for disease detection, and to vaccinate wild foxes. Between transect trapping and grid trapping, 171 foxes were captured on San Miguel in 2013. Of those foxes, 121 were vaccinated against rabies and 107 were vaccinated against distemper. On San Miguel we follow 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). 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 2013, we handled 171 islandwide). Thus we have established a demographic core of about 100 animals vaccinated against CDV. But it is not a geographic core; those vaccinated animals do not occur in one area of the island (Fig. 15). It does nonetheless represent a sample of foxes which could be used to initiate captive breeding, should a CDV outbreak occur on the island.

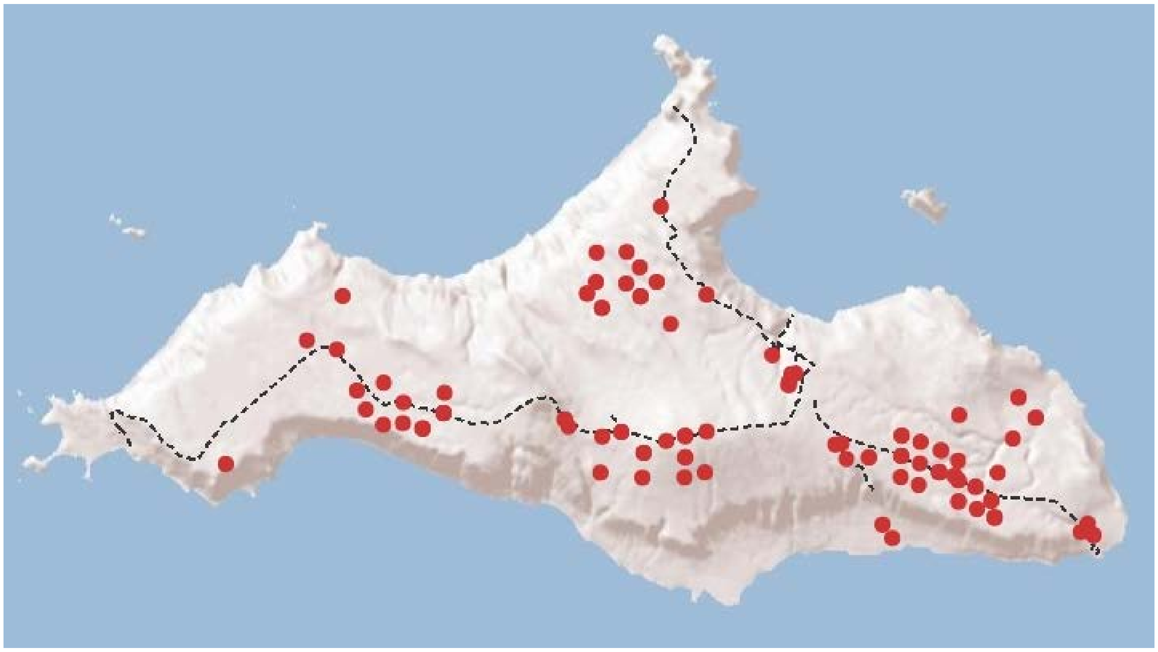

Figure 15. Capture locations of island foxes (n = 107) vaccinated against canine distemper virus on San Miguel Island, 2013.

During the 2013 we maintained a sample of ≥ 20 unvaccinated, radiocollared juvenile foxes, to act as sentinel animals for detection of pathogen outbreaks. There are currently 33 sentinel animals on San Miguel.

In 2013, blood samples were collected from 138 San Miguel foxes.

***Future Plans***

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 2014 on the 4 small grids to estimate population size and reproductive effort. A subset (80-100) of the foxes trapped in 2013 will be vaccinated against canine distemper virus to form a “vaccinated core” (as opposed to a geographic core) which would survive future outbreaks (provided vaccine is available). All captured foxes will be vaccinated against rabies. In 2013 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 2013 we maintained a sample of 38-56 radiocollared foxes on Santa Rosa, and by the end of 2013 there were 51 radiocollared foxes on the island. Annual survival for Santa Rosa Island foxes in 2013 was 94% (92% CI = 89-98%) (Fig. 4). An annual survival rate of 80% is generally required for a stable or increasing fox population (Roemer et al. 2001). Three radiocollared foxes died in 2013, from unknown causes, but none from predation (i.e., there were none of the typical signs of golden eagle predation) (Table 7). The very high survival rate stands in contrast to the lower rate on San Miguel. High survival accounts somewhat for the continued increase in the fox population, and indicates the population is not yet approaching carrying capacity, as the San Miguel population is.

Table 7. Island fox mortalities, Santa Rosa Island, 2013.

| PIT Tag | ID | Sex | Born | Age | Died | Mortality Cause |
|---|---|---|---|---|---|---|
| 12270 | M23 | M | Captive | 6 | 1/7/2013 | Unknown |
| 17137 | M106 | M | Wild | 1 | 9/9/2013 | Unknown |
| 16043 | M110 | M | Wild | 0 | 12/16/2013 | Unknown |

### ***Wild Population Monitoring***

Trapping was conducted on the 18 “ladder” grids (Fig. 3) from mid-July through early September. A total of 152 foxes (127 adults and 25 pups) were trapped on grids, and density estimates for the grids ranged from 0 – 9 foxes/km$^2$ (Table 8). When the average density of 3.4 foxes/km$^2$ was applied to the island area (216 km$^2$), the estimated islandwide adult population was 732 foxes, with an 80% confidence interval of 641-824 and a coefficient of variation of 0.10 (Table 8). Including pups in the analysis resulted in an islandwide population estimate of 894 foxes (80% CI = 793-995; Table 9).The sex ratio was close to even for adults but favored males in pups (Table 10), while the ratio of pups to females was relatively low (0.39, compared to 1.04 in 2012).

Since the predation-caused decline in 2010, Santa Rosa foxes have increased dramatically (Fig. 16). The annual rate of increase, or lambda, was 45% for adults, and 40% for all foxes (adults and pups combined), in 2013. The adult population level of >700 foxes is the highest post-recovery estimate for either San Miguel or Santa Rosa. The Santa Rosa 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, despite the fact that resources may have been affected by the recent drought.

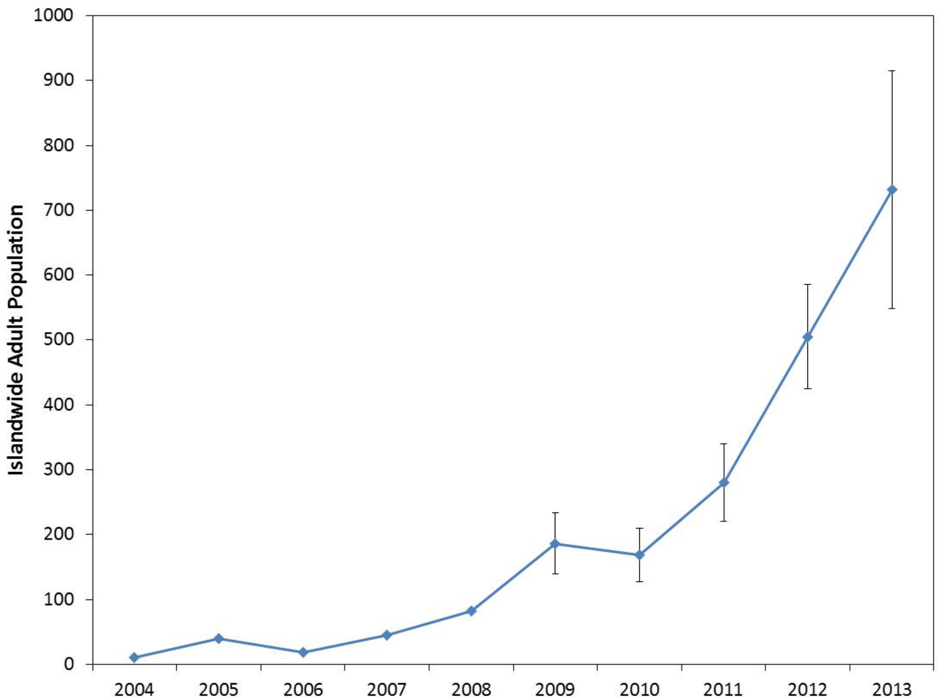


Figure 16. Islandwide adult population estimate, with 80% confidence interval, for Santa Rosa island foxes, from MNKA (2004-2008) and grid-based density estimation (2009-2013).

Table 8. Adult density estimates for ladder grids, Santa Rosa Island, 2013.

| Grid | Dates Trapped | Indiv. | Density Foxes/km$^2$ | SE | CV |
|---|---|---|---|---|---|
| Trancion Canyon Grid | 7/24 - 7/29 | 3 | 1.4 | 0.924 | 0.64 |
| Johnson's Lee Grid | 7/24 - 7/30 | 0 | 0.0 | 0.000 | -- |
| Burma Road Grid | 7/24 - 7/31 | 8 | 3.8 | 1.467 | 0.39 |
| China Camp Grid | 7/24 - 7/32 | 10 | 4.8 | 1.648 | 0.35 |
| Signal Road Grid | 7/31 - 8/5 | 13 | 6.2 | 1.900 | 0.31 |
| Lighthouse Road Grid | 8/1 -8/6 | 2 | 1.0 | 0.833 | 0.82 |
| Sierra Pablo Grid | 8/7 - 8/13 | 8 | 3.8 | 1.470 | 0.38 |
| Wreck Canyon Grid | 8/7 - 8/14 | 7 | 3.3 | 1.373 | 0.41 |
| Quemada Canyon Grid | 8/7 - 8/15 | 6 | 2.9 | 1.274 | 0.44 |
| Old Ranch Grid | 8/7 - 8/16 | 10 | 4.8 | 1.670 | 0.35 |
| Verde Canyon Grid | 8/14 - 8/19 | 9 | 4.3 | 1.568 | 0.36 |
| Dry Canyon Grid | 8/14 - 8/20 | 8 | 3.8 | 1.479 | 0.38 |
| Pocket Field Grid | 8/21 - 8/26 | 4 | 1.9 | 1.051 | 0.55 |
| Bee Canyon Grid | 8/21 - 8/27 | 5 | 2.4 | 1.174 | 0.49 |
| Arlington Canyon Grid | 8/21 - 8/28 | 3 | 1.4 | 0.930 | 0.64 |
| Arlington Springs Grid | 8/21 - 8/29 | 18 | 8.6 | 2.299 | 0.27 |
| Telephone Road Grid | 8/28 - 9/2 | 8 | 3.8 | 1.465 | 0.38 |
| Carrington Point Grid | 8/28 - 9/3 | 5 | 2.5 | 1.241 | 0.49 |
| average | | | 3.4 | | 0.10 |

*CV = coefficient of variation

Table 9. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2009-2013; program Density) and from transect trapping (2003-2008 MNKA), Santa Rosa Island.

| | Adults | | | | | Total (adults plus pups) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **n** | **N** | **SE** | **80% CI** | **λ** | **n** | **N** | **SE** | **80% CI** | **λ** |
| 2003 | | | | | | | 12 | | | |
| 2004 | | | | | | | 14 | | | 1.16 |
| 2005 | | | | | | | 32 | | | 2.29 |
| 2006 | | | | | | | 40 | | | 1.25 |
| 2007 | | | | | | | 62 | | | 1.55 |
| 2008 | | | | | | | 122 | | | 1.97 |
| 2009 | 59 | 187 | 36.34 | 140-233 | | 85 | 389 | 59.88 | 313-466 | 3.18 |
| 2010 | 49 | 169 | 32.29 | 128-210 | 0.90 | 64 | 292 | 46.08 | 233-351 | 0.75 |
| 2011 | 57 | 280 | 46.89 | 220-340 | 1.66 | 84 | 449 | 64.78 | 366-532 | 1.54 |
| 2012 | 99 | 505 | 61.47 | 426-584 | 1.80 | 152 | 637 | 59.65 | 561-713 | 1.42 |
| 2013 | 127 | 732 | 71.44 | 641-824 | 1.45 | 152 | 894 | 78.85 | 793-995 | 1.40 |

Table 10. Number of foxes captured, by age and sex, on 18 Santa Rosa grids, 2013.

| | **Male** | **Female** | **Total** |
|---|---|---|---|
| Pups | 18 | 7 | 25 |
| Adults | 62 | 65 | 127 |
| Total | 80 | 72 | 152 |

To determine whether the Santa Rosa population was approaching biological recovery, we plotted 3-year averages of adult population size and adult mortality using the spreadsheet tool developed by Vicki Bakker of Montana State University. The plots of 3-year averages for 2006-2013 (Fig. 17) show that the Santa Rosa subspecies, for the first time, has a combination of population size and mortality values that result in an extinction risk of <5%. Because five such consecutive values are required for delisting (USFWS 2012), the Santa Rosa subspecies will likely be considered biologically recovered in four years (2017).

### *Vaccination of Wild Foxes, Establishment of Sentinel Animals and Collection of Biological Samples*

In addition to the grids, transect trapping was conducted to complete affixing radiocollars, establish sentinel animals for disease detection, and to vaccinate wild foxes. Between transect trapping and grid trapping, 310 foxes were captured on Santa Rosa in 2013. Of those foxes, 166 were vaccinated against rabies and 109 were vaccinated against distemper. As on San Miguel, on Santa Rosa we had been previously following the guidelines for small populations (< 100), which recommends that all foxes should be vaccinated for both CDV and rabies.

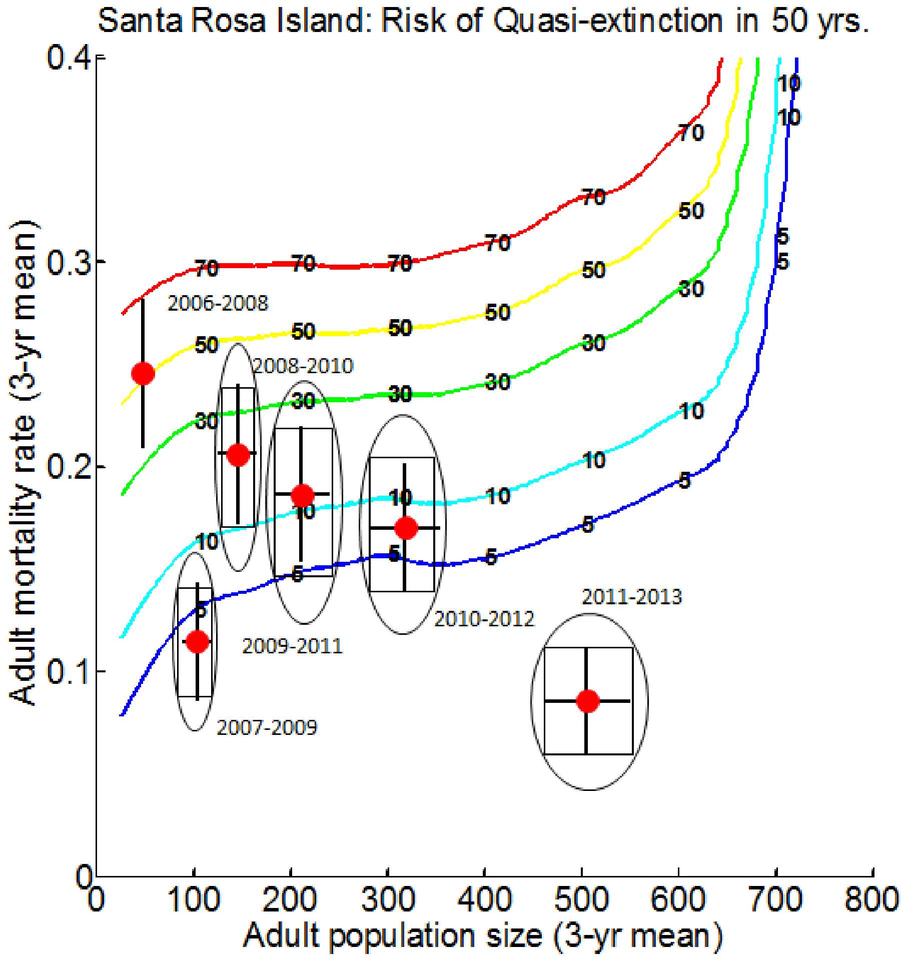


Figure 17. Extinction risk for Santa Rosa island foxes under 2006-2013 averages for adult mortality and population size.

The guidelines for vaccination recommend moving to the vaccinated core strategy when the population reaches 50% of the recovery goal. With the Santa Rosa population now at or exceeding half of its pre-decline level and at low demographic risk of extinction, we have shifted to the vaccinated core strategy. However, in a single trapping season on Santa Rosa we have previously been unlikely to trap and handle 80-100 foxes in one portion of the island, so until now, our sample of vaccinated foxes has not been a geographic core (Fig. 18) . Given the large number of foxes we caught in 2013 (>300), it may be time to move to a geographic vaccinated core on Santa Rosa.

During the 2013 trapping season we maintained a sample of ≥ 20 unvaccinated, radiocollared juvenile foxes, to act as sentinel animals for detection of pathogen outbreaks. At the end of 2013 there were 33 sentinel animals on Santa Rosa.

In 2013 we collected blood samples for archiving and potentially for serology, scat for a St. Louis Zoo hormone study, urine to screen for leptospirosis, and whiskers for a stable isotope study of fox diet (Table 11).

Table 11. Biological samples collected from Santa Rosa Island foxes, 2013.

| Sampling type | Number of samples | Repository |
|---|---|---|
| Blood | 344 | NPS, AMNH |
| Scat (hormone study) | 66 | St. Louis Zoo |
| Urine | 189 | UCLA, NIH |
| Whiskers | 351 | University of Wyoming |

Figure 18. Capture locations of island foxes (n = 109) vaccinated against canine distemper virus on Santa Rosa Island, 2013.

### *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 2013 we captured 129 individual skunks, a decrease from the number we captured in 2012 (152). The number of individual skunks and density varied widely on the 18 ladder grids (Table 12), most likely due to variation in habitat type and/or quality among grids. Applying the average density of 15.8 skunks/$km^2$ to the island's area (216 $km^2$) resulted in an islandwide density estimate of 3,404 skunks, with an 80% confidence interval of 2,979 – 3,829 and coefficient of variation of 0.10. This is the first year that the number of skunks caught on the grid was less than the number of foxes. With an islandwide estimate of 894 foxes, skunks were about 4 times as abundant as foxes (Table 12). The skunk population has been fairly numerous, and stable, since 2009.

Table 12. Density of island spotted skunks on ladder grids, Santa Rosa Island, 2013.

| Grid | Dates Trapped | Indiv. | Density Skunks/km$^2$ | SE | CV* |
|---|---|---|---|---|---|
| Trancion Canyon Grid | 7/24 - 7/29 | 7 | 14.7 | 5.99 | 0.41 |
| Johnson's Lee Grid | 7/24 - 7/30 | 10 | 21.1 | 7.216 | 0.34 |
| Burma Road Grid | 7/24 - 7/31 | 9 | 20.9 | 7.59 | 0.36 |
| China Camp Grid | 7/24 - 7/32 | 4 | 8.3 | 4.558 | 0.55 |
| Signal Road Grid | 7/31 - 8/5 | 6 | 12.6 | 5.536 | 0.44 |
| Lighthouse Road Grid | 8/1 -8/6 | 7 | 14.8 | 6.008 | 0.41 |
| Sierra Pablo Grid | 8/7 - 8/13 | 7 | 14.6 | 5.956 | 0.41 |
| Wreck Canyon Grid | 8/7 - 8/14 | 12 | 25.1 | 7.883 | 0.31 |
| Quemada Canyon Grid | 8/7 - 8/15 | 14 | 29.3 | 8.583 | 0.29 |
| Old Ranch Grid | 8/7 - 8/16 | 3 | 8.3 | 5.314 | 0.64 |
| Verde Canyon Grid | 8/14 - 8/19 | 5 | 10.6 | 5.101 | 0.48 |
| Dry Canyon Grid | 8/14 - 8/20 | 3 | 7.0 | 4.529 | 0.64 |
| Pocket Field Grid | 8/21 - 8/26 | 3 | 8.2 | 5.25 | 0.64 |
| Bee Canyno Grid | 8/21 - 8/27 | 6 | 12.7 | 5.598 | 0.44 |
| Arlington Canyon Grid | 8/21 - 8/28 | 7 | 16.6 | 6.796 | 0.41 |
| Arlington Springs Grid | 8/21 - 8/29 | 1 | 4.6 | 6.138 | 1.33 |
| Telephone Road Grid | 8/28 - 9/2 | 8 | 18.6 | 7.156 | 0.38 |
| Carrington Point Grid | 8/28 - 9/3 | 17 | 35.7 | 9.599 | 0.27 |
| average | | | 15.8 | | 0.10 |

*CV = coefficient of variation

Table 13. Number of individuals caught on grids, and islandwide population estimates, with 80% confidence intervals (from program Density), for island foxes and island spotted skunks, Santa Rosa Island, 2009-2013.

| | Indiv. on Grids | | Islandwide Pop'n Estimate | |
|---|---|---|---|---|
| | Foxes | Skunks | Foxes | Skunks |
| 2009 | 69 | 130 | 389 (313 - 466) | 3,014 (2,652 – 3,376) |
| 2010 | 64 | 71 | 292 (233 – 351) | 2,911 (2,373 – 3,448) |
| 2011 | 84 | 104 | 449 (366 - 532) | 3,166 (2,653 – 3,678) |
| 2012 | 152 | 155 | 637 (561 – 713) | 4,282 (3,718 – 4,846) |
| 2013 | 152 | 129 | 894 (793 – 995) | 3,404 (2,979 – 3,406) |

Island foxes and island spotted skunks are thought to be competitors, with island foxes gaining the upper hand via interference competition (Roemer et al. 2002, Jones et al. 2008). Skunks increased in abundance on both Santa Rosa and Santa Cruz islands when foxes declined, and skunks are occasionally eaten by island foxes (Cypher et al. 2011). Although one might thus expect skunks to decline in abundance as the Santa Rosa fox population recovers; this has not been the case. The islandwide skunk population estimate increased from 2009-2012, and the number of individual skunks caught on grids did not decline until this year (Table 13). The relative decline in skunks recorded in 2013 may be the beginning of the anticipate skunk population decline, as the fox population continues to increase.

***Future Plans***

Monitoring results from 2013 indicate a rapidly growing island fox population, with high survival, but still at <50% of likely historic levels. Intensive island fox monitoring will continue in 2013. We will maintain a sample of >50 radiocollared foxes on the island, and we will conduct population monitoring in summer/fall 2014, using small, “ladder” grids (Rubin et al. 2007). All newly encountered wild animals will be PIT-tagged, all captured foxes will be vaccinated against rabies and 80-100 will be vaccinated against canine distemper virus. Blood samples will be drawn from a subset of the island foxes we trap.

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