



# Island Fox Recovery Program

## *Channel Islands National Park 2014 Annual Report*

Natural Resource Report NPS/MEDN/NRR—2015/1047



**ON THE COVER**

Female island fox 86401, San Miguel Island, 1994

---

# **Island Fox Recovery Program**

## *Channel Islands National Park 2014 Annual Report*

Natural Resource Report NPS/MEDN/NRR—2015/1047

Timothy J. Coonan, Angela Guglielmino and Robyn Shea

National Park Service  
Channel Islands National Park  
1901 Spinnaker Drive  
Ventura, California 93001

September 2015

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner.

This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available from the Mediterranean Coast Network of the National Park Service website (<http://science.nature.nps.gov/im/units/medn/>) and the Natural Resource Publications Management website (<http://www.nature.nps.gov/publications/nrpm/>). To receive this report in a format optimized for screen readers, please email [irma@nps.gov](mailto:irma@nps.gov).

Please cite this publication as:

Coonan, T. J., A. Guglielmino, and R. Shea. 2015. Island fox recovery program: Channel Islands National Park 2014 annual report. Natural Resource Report NPS/MEDN/NRR—2015/1047. National Park Service, Fort Collins, Colorado.

# Contents

	Page
Figures.....	v
Tables.....	vii
Executive Summary .....	vii
Acknowledgements.....	xiii
Introduction.....	1
Background.....	1
Recovery Actions .....	1
Ecological Effects of Changes in Fox Abundance .....	3
Integrated Island Fox Recovery Team .....	4
Island Foxes and Long-term Ecological Monitoring.....	5
Methods.....	7
Population Monitoring of Foxes and Skunks .....	7
Survival and Mortality Causes .....	10
Vaccination of Wild Foxes and Establishment of Sentinel Animals.....	10
Santa Cruz Island Campground Foxes .....	11
Results and Discussion .....	12
San Miguel Island.....	12
Mortality Monitoring.....	12
Wild Population Abundance and Density .....	15
Weights and Body Condition .....	20
Vaccination of Wild Foxes, Establishment of Sentinel Animals and Collection of Blood Samples.....	22
Future Plans for San Miguel Island.....	22
Santa Rosa Island .....	23
Mortality Monitoring.....	23
Wild Population Abundance and Density .....	23
Vaccination of Wild Foxes, Establishment of Sentinel Animals and Collection of Biological Samples.....	25

## Contents (continued)

	Page
Density of Island Spotted Skunks.....	26
Future Plans for Santa Rosa Island.....	28
Santa Cruz Island Campground Foxes .....	29
Literature Cited .....	31

# Figures

	Page
Figure 1. Annual estimated number of adult island foxes for San Miguel and Santa Rosa.....	x
Figure 2. Location of trapping grids, San Miguel Island. ....	8
Figure 3. Location of trapping grids, Santa Rosa Island.....	9
Figure 4. Location of trapping sites in Upper Campground (triangles) and Lower Campground, Scorpion Ranch, Santa Cruz Island.....	11
Figure 5. Annual survival for island foxes, with 80% confidence intervals, San Miguel and Santa Rosa islands.....	12
Figure 6. Annual precipitation for the water year (October 1 - September 30), Black Mountain, Santa Rosa Island. ....	14
Figure 7. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2014). ....	15
Figure 8. Individual grid densities, San Miguel Island, 2006-2014.....	16
Figure 9. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2014). ....	17
Figure 10. Reproductive effort as estimated by the ratio of pups to adult females, San Miguel Island, 1993-2014.....	18
Figure 11. Total number and age class of individuals trapped on 4 grids, San Miguel Island, 2006-2014. ....	18
Figure 12. Estimated total (adult and pups) islandwide population, with 80% CI, San Miguel Island. ....	19
Figure 13. Extinction risk for San Miguel island foxes under 2006-2014 averages for adult mortality and population size.....	19
Figure 14. Average annual weights for adult island foxes on a) San Miguel and b) Santa Rosa Islands. ....	20
Figure 15. Body condition scores for island foxes on a) San Miguel and b) Santa Rosa in 2013 -2014.....	21
Figure 16. Islandwide adult population estimate, with 80% confidence interval, for Santa Rosa Island foxes, from MNKA (2004-2008) and grid-based density estimation. ....	24
Figure 17. Extinction risk for Santa Rosa Island foxes under 2006-2014 averages for adult mortality and population size, 2006-2014.....	26
Figure 18. Age structure of foxes captured at the Scorpion Campground, Santa Cruz Island, July 2014.....	29

## Figures (continued)

	Page
Figure 19. Body condition scores for foxes captured at the Scorpion Campground, Santa Cruz Island, July 2014 (1 = emaciated, 2 = thin, 3 = optimal, 4 = fat) .....	30

# Tables

	Page
Table 1. Descriptions of body condition scores used to rate captured foxes.....	6
Table 2. Mortalities of radiocollared island foxes on San Miguel, 2014-2015. ....	13
Table 3. Adult density estimates for small grids, San Miguel Island, 2014. ....	16
Table 4. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2006-2014; program Density) and from transect trapping (2005, MNKA), San Miguel Island. ....	16
Table 5. Adult, pup and total captures on monitoring grids, San Miguel Island, 2009-2014.....	17
Table 6. Number of foxes captured, by age and sex on 4 grids on San Miguel, 2014. ....	18
Table 7. Vaccinations administered and biological samples collected from San Miguel Island foxes and Santa Rosa Island foxes, 2014. ....	22
Table 8. Island fox mortalities, Santa Rosa Island, 2014. ....	23
Table 9. Adult density estimates for ladder grids, Santa Rosa Island, 2014.....	24
Table 10. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2009-2014; program Density) and from transect trapping (2003-2008; MNKA), Santa Rosa Island. ....	25
Table 11. Number of foxes captured, by age and sex, on 18 Santa Rosa grids, 2014. ....	25
Table 12. Density of island spotted skunks on ladder grids, Santa Rosa Island, 2014. ....	27
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, 2009-2014.....	28



## Executive Summary

In 2014 the National Park Service (NPS) continued to implement recovery actions for endangered island fox subspecies on San Miguel Island (*Urocyon littoralis littoralis*), Santa Rosa Island (*U. l. santarosae*), and (in partnership with The Nature Conservancy) Santa Cruz Island (*U. l. santacruzae*). The NPS is the lead for monitoring island foxes on San Miguel and Santa Rosa Islands. Annual monitoring indicates that both populations have generally increased over time. 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. The San Miguel population decreased somewhat in 2014, likely due to the three-year drought and high population density, whereas the Santa Rosa population stayed at approximately the same population size as in 2013.

The three subspecies, 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 2014 the San Miguel island fox population estimate was 470 adults (Fig. 1) and 515 total foxes, numbers which are greater than population estimates prior to the predation-caused decline of the 1990s. The San Miguel population has apparently reached carrying capacity; the total number of foxes has hovered around 550 since 2010. In 2014 the Santa Rosa population estimate was 826 adults and 877 total foxes. There was no formal population monitoring on Santa Rosa Island prior to bringing all island foxes into captivity in 2000. The current population on Santa Rosa Island is estimated to represent about 2/3 of pre-decline numbers, and of carrying capacity, if pre-decline densities on that island were similar to those on Santa Cruz.

Annual survival of foxes on San Miguel decreased, for the third straight year, to 76%, likely due to density-dependent effects, continued drought, and the appearance of a novel acanthocephalan parasite. Fifteen radiocollared foxes died on San Miguel in 2014, and 5 in early 2015, none from eagle predation. Seven of the 8 foxes which could be necropsied had evidence of heavy infestation by an acanthocephalan parasite (*Oncicola canis*), along with emaciation and enteritis (inflammation of the small intestine). Annual survival on Santa Rosa was 93% in 2014 and only 5 radiocollared foxes died, all from unknown causes.

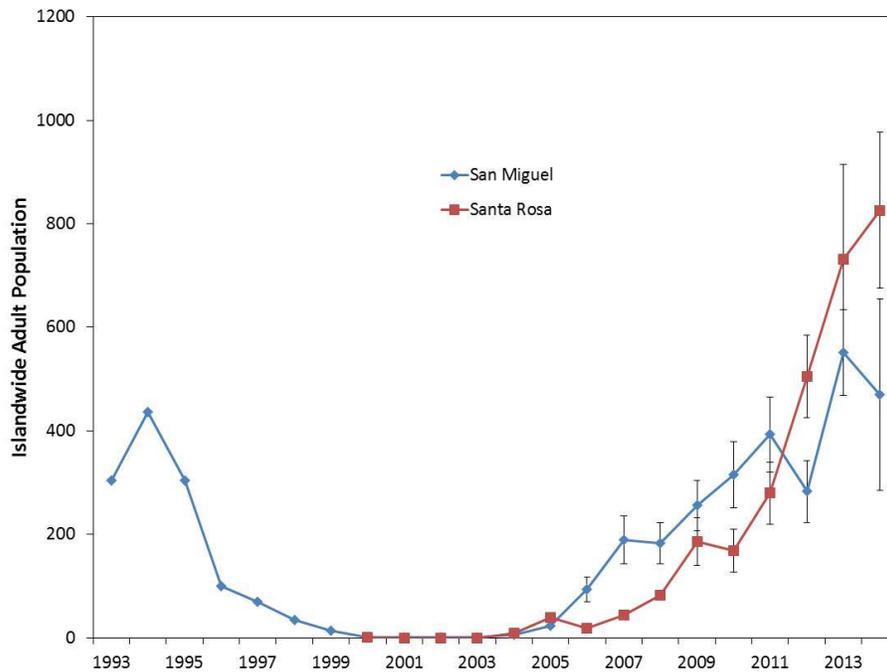


Figure 1. Annual estimated number of adult island foxes for San Miguel and Santa Rosa. 80% confidence intervals are shown for estimates from program Density (estimates from 1993-1998 are from program Capture).

For the second straight year, 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 2014, the same as in 2013.

Data on fox weights and body condition reflect the effect of the current drought and high fox density on San Miguel. Adult weights on San Miguel in 2014 declined for the second straight year, and were the lowest recorded since we began tracking fox weights in 2007. This is not the case on Santa Rosa Island, where fox weights 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 are no doubt lower due to the prolonged drought in southern California. Deer mouse (*Peromyscus maniculatus*) populations on San Miguel have remained low since early

2012. The continued occurrence of the acanthocephalan parasite is worrisome. At this point, the impact of the parasite is unknown, because post-mortality tissue breakdown has prevented pathologists from determining effects on individual foxes. We are awaiting identification of the likely intermediate host for the parasite. 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 6.6 skunks/km<sup>2</sup> and an islandwide estimate of 1,404 skunks, substantially lower than the previous year’s estimate of 3,404 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 second year in which the number of individual skunks captured on the grids (99) was lower than the number of captured foxes (149).

About 58% of trapped foxes were vaccinated against rabies. The number of vaccinates for rabies was 105 on San Miguel and 147 on Santa Rosa. No foxes were vaccinated against canine distemper virus (CDV) in 2014, because the vaccine was not produced by the drug maker (Merial). It is not clear whether the vaccine will be produced again. The absence of the vaccine is problematic, because foxes on all islands have been vaccinated against CDV for a number of years as part of a comprehensive and standardized strategy to prevent an outbreak of CDV in island foxes (such an outbreak was responsible for the catastrophic decline of Santa Catalina island foxes in 1999-2000). Merial produces another CDV vaccine (Recombitek®), and the Fox Health Group will determine whether that would be an acceptable substitute.

In 2014 we trapped foxes in the Scorpion Campground on Santa Cruz Island, which we do in alternate years in order to assess the condition of foxes there. Abundance was greater in the campground in summer 2014 (32 foxes) than in summer 2012 (22 foxes), although there were no pups recorded in 2014. High survival of pups from previous years may have discouraged reproduction among campground foxes. Foxes were in relatively good physical condition, more similar to Santa Rosa foxes than to San Miguel foxes.



## 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), Don Jones, Andy Abate, and a number of volunteers: Debbie Watson Alexander, Stacy Baker, Adam Chrisite, Brian Connolly, Jill Estrada, Dailee Fagnant, Stephanie Klein, Peter Larramendy, Natalie Moore and Greg Senning. 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 Beem, Jen Kennedy and Kristen Wieners. 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, especially Dave Garcelon, Brian Hudgens, and Pete Sharpe. 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 Katrina Linton 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 Ostermann-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 fox populations that are biologically recovered (Coonan and Schwemm 2009, Coonan et al. 2010, Coonan et al. 2014). 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-approved elimination of non-native mule deer and elk from Santa Rosa Island has eliminated the last of the non-native prey base from the northern Channel Islands.

The final island fox recovery plan was recently released to the public (US Fish and Wildlife Service 2015a). 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. The four island fox subspecies had reached these demographic goals, as of 2015. The U.S. Fish and Wildlife Service announced its intention to initiate a status review for the four listed subspecies, to determine if reclassification (delisting or downlisting) is appropriate (U.S. Fish and Wildlife Service 2015b). The four subspecies could be proposed for delisting as soon as spring 2016.

### **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 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 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.

This report presents the results of our efforts in 2014 to 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 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 2015).

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.

<b>Score</b>	<b>Condition</b>	<b>Description</b>
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 Sana Rosa Island and August – September on San Miguel Island. On both islands, transect trapping to manage collars, establish sentinels and administer vaccines was conducted from July 2014 through January 2015. 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 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 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 (for a stable isotope study of fox diets), and urine (the latter via cystocentesis, to investigate whether foxes were shedding *Leptospira* bacteria). A portion of the serum from each was set aside for archiving in a -80°C freezer at park headquarters in Ventura, California. Additionally, a portion of the blood samples collected were sent to the American Museum of Natural History, under a national agreement between that institution and the NPS for archiving biological specimens of endangered species.

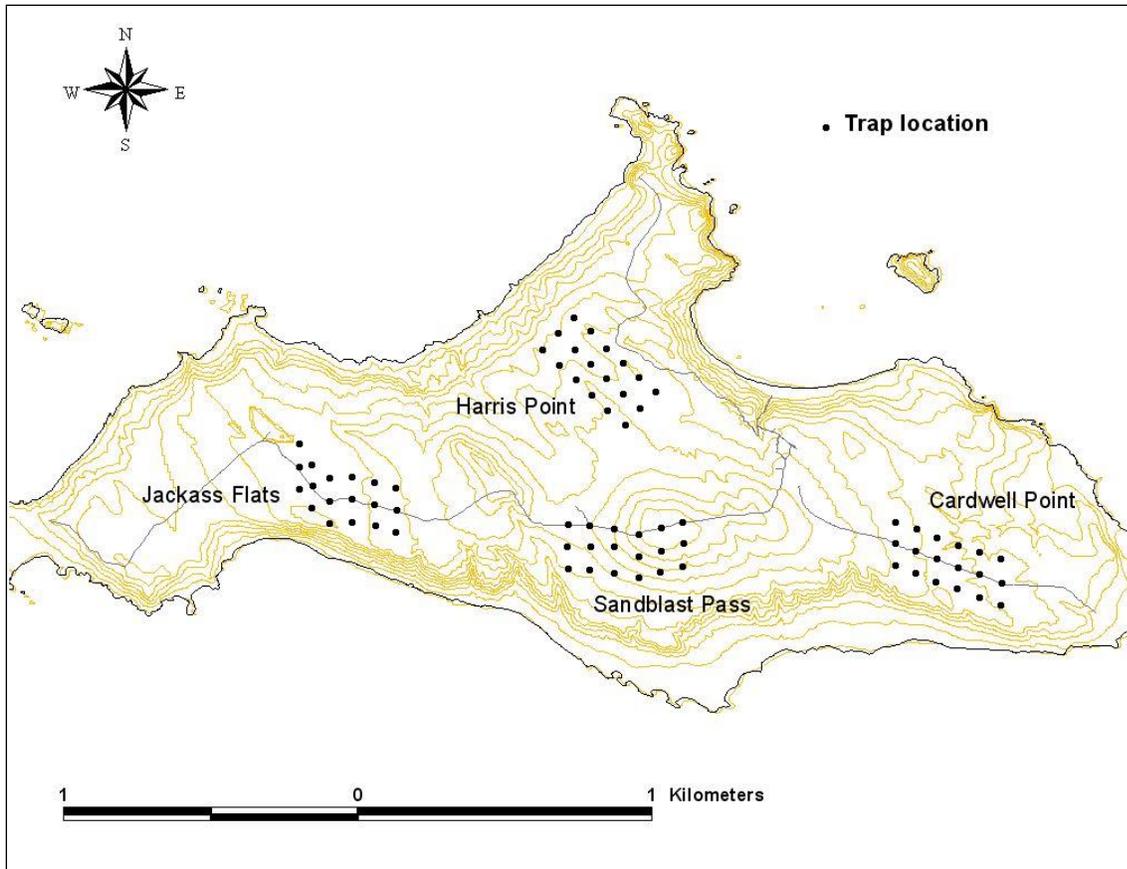


Figure 2. Location of trapping grids, San Miguel Island.

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.

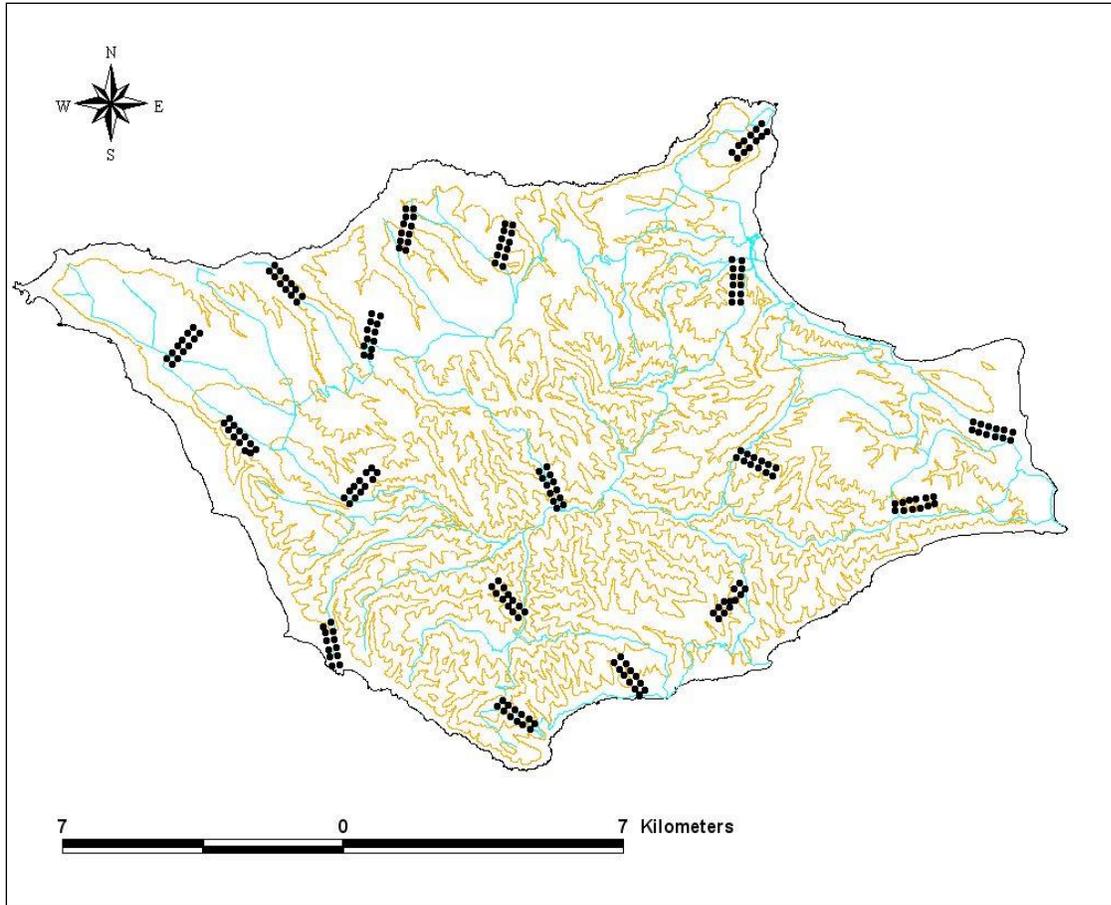


Figure 3. Location of trapping grids, Santa Rosa Island.

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 ( $g_0$ ), 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  $g_0$  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 of sex and age structure in the population. Collared foxes were monitored at least weekly to determine their general location and signal type (normal or mortality). If a mortality signal was detected, the dead fox was located and recovered. Data collected at the site prior to removing the carcass included: 1) any information that might indicate cause of mortality, 2) the position of the carcass with respect to its surroundings, including digital photographs, and 3) the general condition of the animal (e.g., eviscerated, intact, damage by insect scavengers, etc.). The location of the carcass was recorded via GPS, and a general description of the habitat was recorded.

Carcasses were tagged with pertinent identification, date and location information. If 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 developed by the U.S Fish and Wildlife Service for its island fox recovery plan (U.S. Fish and Wildlife Service 2015). 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). In all previous years selected animals were vaccinated with Purevax Ferret Distemper Vaccine for CDV and Imrab 3 for rabies (Merial, Inc., Atlanta, GA). However, Merial has discontinued production of the Purevax Ferret Distemper Vaccine, and so not foxes were vaccinated against CDV in 2014.

In 2014 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). We have been able to maintain a sample of sentinel animals on each island since 2010, and during trapping season in 2013 we affixed radiocollars to a number of unvaccinated juvenile foxes for this purpose.

### **Santa Cruz Island Campground Foxes**

We investigated the status and condition of foxes in the Scorpion Campground on Santa Cruz Island by trapping foxes on transects in July 2014 and in January 2015. We captured foxes in both the Upper Campground and Lower Campground (Fig. 4). Transects were trapped for 6 consecutive nights. Captured foxes were marked with PIT tags, and information was collected on age, sex, weight, body condition, general health and injuries. Blood samples were obtained from all foxes.



Figure 4. Location of trapping sites in Upper Campground (triangles) and Lower Campground, Scorpion Ranch, Santa Cruz Island.

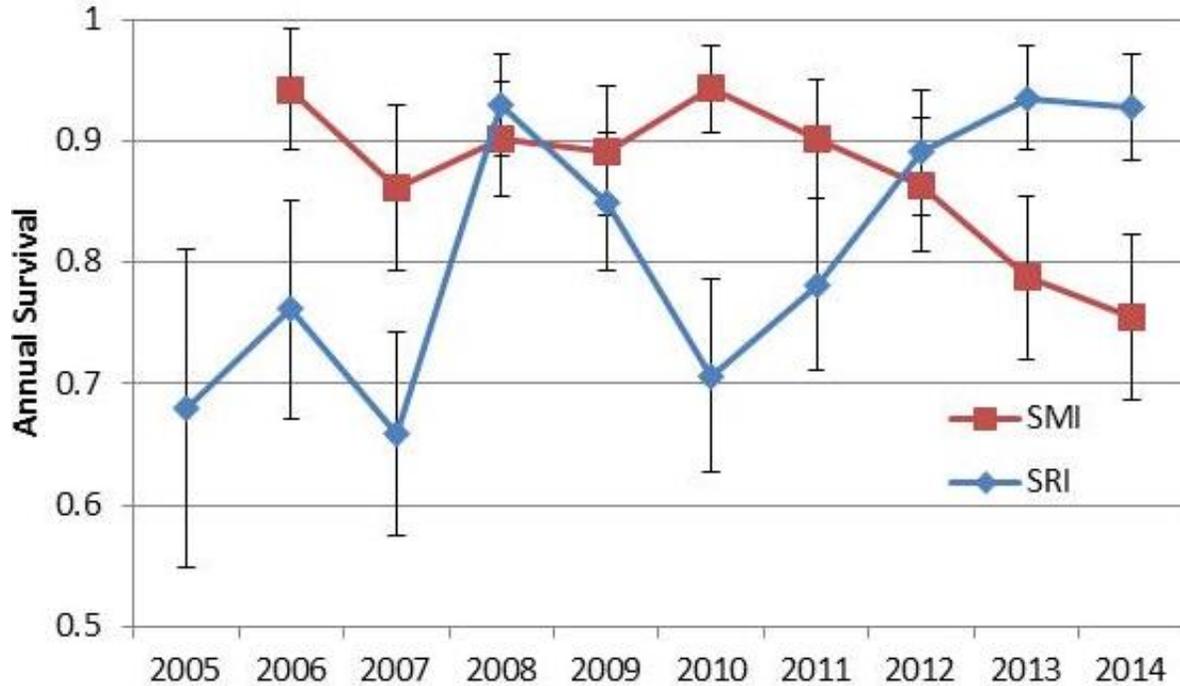


Figure 5. Annual survival for island foxes, with 80% confidence intervals, San Miguel and Santa Rosa islands.

## Results and Discussion

### San Miguel Island

#### ***Mortality Monitoring***

Throughout 2014 we maintained a sample of 41-53 radiocollared foxes on San Miguel, and by the end of the year there were 53 radiocollared foxes being monitored. Annual Kaplan-Meier survival for San Miguel island foxes in 2014 was 76.0% (80% CI = 69-82%). Annual survival decreased for the fourth straight year on San Miguel (Fig. 5). Fifteen radiocollared foxes died in 2014, none from eagle predation (Table 2). The high mortality continued into early 2015; five radiocollared foxes died during January-March.

Some of the high mortality is no doubt due to the density-dependent effects of extended drought. Precipitation records from nearby Santa Rosa Island indicate that 2014 was the third year of an extended regional drought (Fig. 6). Island fox densities on San Miguel are among the highest recorded on that island, 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 2012-2014. Of the 8 fox carcasses for which necropsies could be performed, 7 were emaciated (Table 2; also see section on weights and body condition, below).

Another factor in San Miguel island fox mortality is the recent appearance of an acanthocephalan parasite that has not been recorded in island foxes before. Also called spiny-headed worms, acanthocephalans 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, lesions and peritonitis. Acanthocephalans (*Profilicolis* spp.) are known to cause mortalities in sea otters (*Enhydra lutris*).

Table 2. Mortalities of radiocollared island foxes on San Miguel, 2014-2015.

PIT Tag	ID	Sex	Born	Age	Date	Mortality Cause
75104	F362	F	Wild	3	1/8/2014	Unknown (deshicated)
E7059	M260	M	Wild	5	1/15/2014	Emaciation, enlarged thyroid glands pulmonary hypertrophy/hyperplasia
92634	F381	F	Wild	1	2/5/2014	Unknown (deshicated)
F4B39	F322	F	Wild	--	2/11/2014	Unknown (deshicated)
39002	M307	M	Wild	0	2/19/2014	Emaciation, Acanthocephalans, enteritis
C3B3E	M274	M	Wild	5	3/2/2014	Emaciation, Acanthocephalans, enteritis
56C06	F358	F	Wild	4	3/19/2014	Unknown (advanced decomposition)
68110	M298	M	Wild	2	4/4/2014	Hemoperitoneum and hemothorax, melena - unknown cause of these
49488	F382	F	Wild	2	7/9/2014	Unknown (deshicated)
F5200	M278	M	Wild	4	8/31/2014	Emaciation, Acanthocephalans, enteritis, <i>Spirocerca</i>
D0D17	M256	M	Wild	6	9/8/2014	Fresh, but no necropsy report
91785	M295	M	Wild	2	10/2/2014	Emaciation, massive Acanthocephalans, enteritis
B112A	M223	M	Wild	9	12/9/2014	Fresh, but no necropsy report
A7B60	F370	F	Wild	7	12/26/2014	No necropsy report
45A3D	M249	M	Wild	8	12/28/2014	Fresh, no necropsy report
61981	F379	F	Wild	2	1/9/2015	Emaciation, moderate Acanthocephalans, enteritis, <i>Spirocerca</i> , lungworms; lesions, but no ulceration

Table 3. (continued). Mortalities of radiocollared island foxes on San Miguel, 2014-2015.

PIT Tag	ID	Sex	Born	Age	Date	Mortality Cause
59264	M302	M	Wild	1	1/21/2015	Emaciation, a few Acanthocephalans but still had lesions like heavily parasitized animals, <i>Spirocerca</i> , lungworms
24908	M293	M	Wild	7	2/18/2015	No necropsy report
75086	M292	M	Wild	3	2/28/2015	Fresh, no necropsy report
07202	M290	M	Wild	6	3/17/2015	Unknown (deshicated)

Acanthocephalans were first identified in one island fox carcass in January 2012, in which large acanthocephalans were found in the small intestine, and the fox was characterized as “severely parasitized” (L. Woods, California Animal Health and Food Safety Laboratory System, unpubl. data). In 2013, heavy acanthocephalan loads were found in all 5 San Miguel island fox carcasses that were intact enough for necropsy (Coonan et al. 2014). Acanthocephalans were found in 6 of 8 carcasses in 2014-2015, typically in heavy loads (Table 2). The acanthocephalans are associated with emaciation, enteritis (inflammation of the small intestine) and intestinal lesions, and some of the foxes with acanthocephalans also had significant infestation with another parasite, *Spirocerca*. It is unclear whether acanthocephalans are a cause of mortality for island foxes, because the nature and the severity of the lesions are lost quickly through autolysis, and by freezing the carcass; field necropsies may be necessary to reveal the true severity of lesions caused by acanthocephalans (L. Woods, California Animal Health and Food Safety Laboratory System, personal comm.).

The acanthocephalan has yet to be conclusively identified. It has been presumptively identified as *Oncicola canis*, but awaits genetic testing to confirm that (L. Woods, California Animal Health and Food Safety Laboratory System, unpubl. data). The species infects wild carnivores and occasionally domestic dogs on the mainland, and occurs throughout the temperate and tropical zones of the world. Acanthocephalans require two hosts, living in crustaceans and insects as juveniles, and in vertebrates as adults. The intermediate host or hosts for *Oncicola* on San Miguel are unknown.

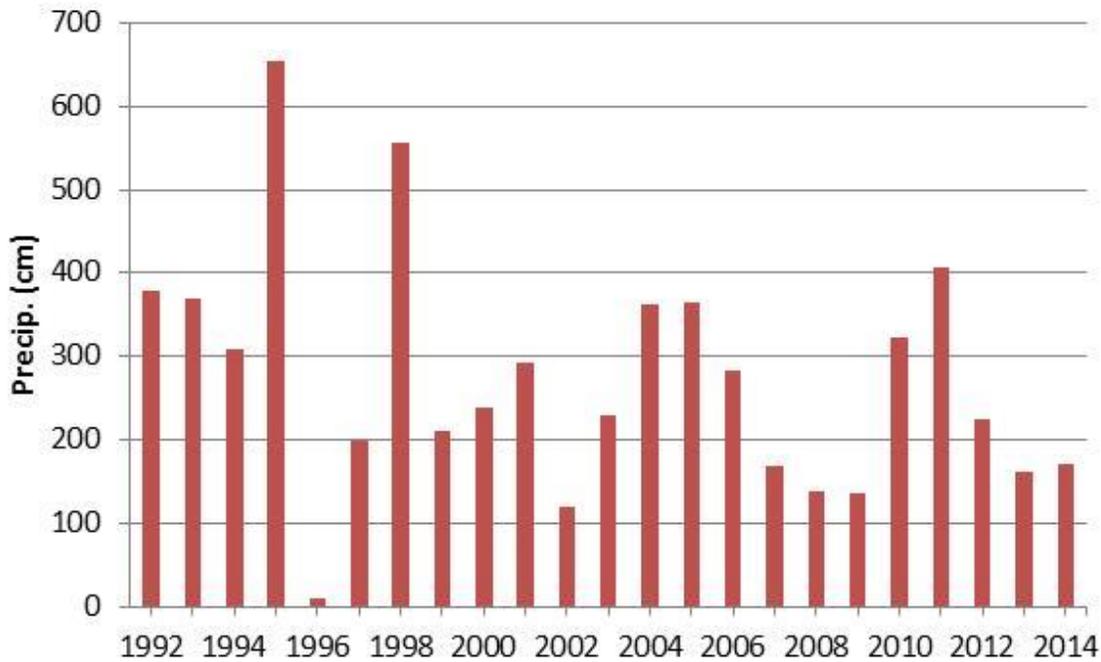


Figure 6. Annual precipitation for the water year (October 1 - September 30), Black Mountain, Santa Rosa Island.

The Island Fox Health Group, a subset of the Island Fox Conservation Working Group, considered the acanthocephalan cases on San Miguel at the 2013 and 2014 working group meetings, and recommended further investigation (Coonan 2013). If molecular methods confirm identification as *Oncicola canis*, 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, and specimens of potential hosts (lizards, mice and invertebrates) have been collected and sent to the California Animal Health and Food Safety Laboratory for testing. The Health Group did not think the current impact on foxes warranted treatment with anthelmintics, though that may be a possibility if a significant number of additional mortalities occurs.

### **Wild Population Abundance and Density**

On San Miguel grids in 2014 we captured 77 foxes a total of 183 times, with an additional 49 foxes caught on transects a total of 105 times. Three pups and 74 adults were trapped on the 4 small grids. Adult density ranged from 10-20 foxes/km<sup>2</sup>, with an average density of 12.2 foxes/km<sup>2</sup> (Table 4). The coefficient of variation for the islandwide density estimate was 0.31 (a CV < 0.20 is desirable [M. Efford, Landcare Research, pers. comm.]). Multiplying the average density by the area of the island (38.6 km<sup>2</sup>) yielded a population estimate of 470 adult foxes, with 80% CI = 420-570 adult foxes. This represents an approximately 15% decrease from the 2013 estimate of 551 foxes (Fig. 7). When pups were included in density estimates, the islandwide population estimate was 515 foxes, with 80% CI = 318-711 (Table 5).

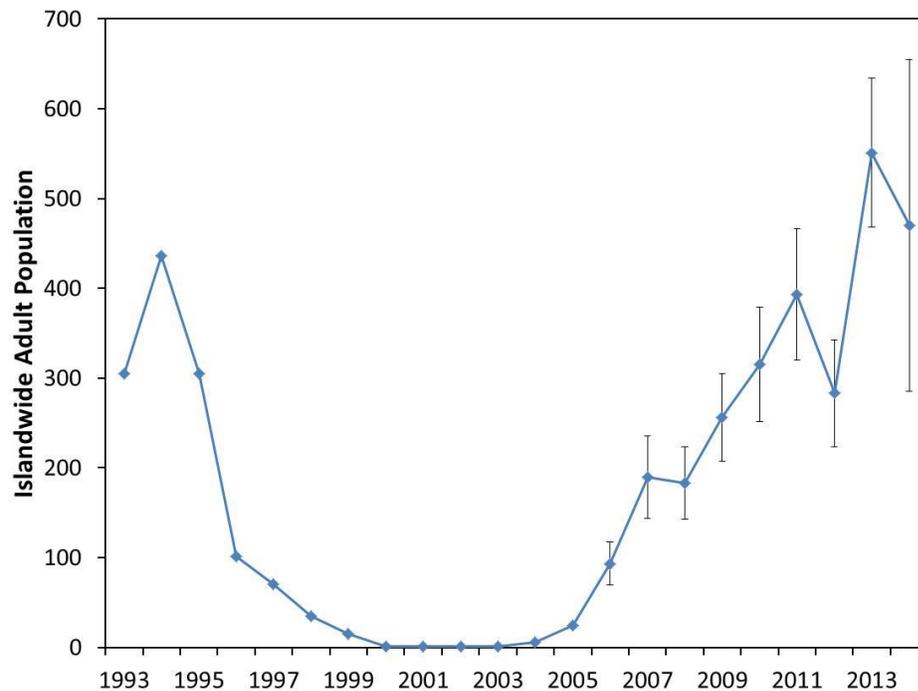


Figure 7. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2014).

Density was considerably higher on the Cardwell grid than on the other grids, all of which decreased in density from 2013-2014 (Fig. 8). This implies that habitat quality/food resources were better in the Cardwell grid area than in other parts of the island. Stable isotope work indicates that island foxes in the Cardwell area consume more vertebrate prey than do foxes in other areas of the island (S. Newsome, University of New Mexico, unpubl. data). Confidence intervals were much higher in 2014 than in other years, perhaps partly because of the difference in density between several of the grids.

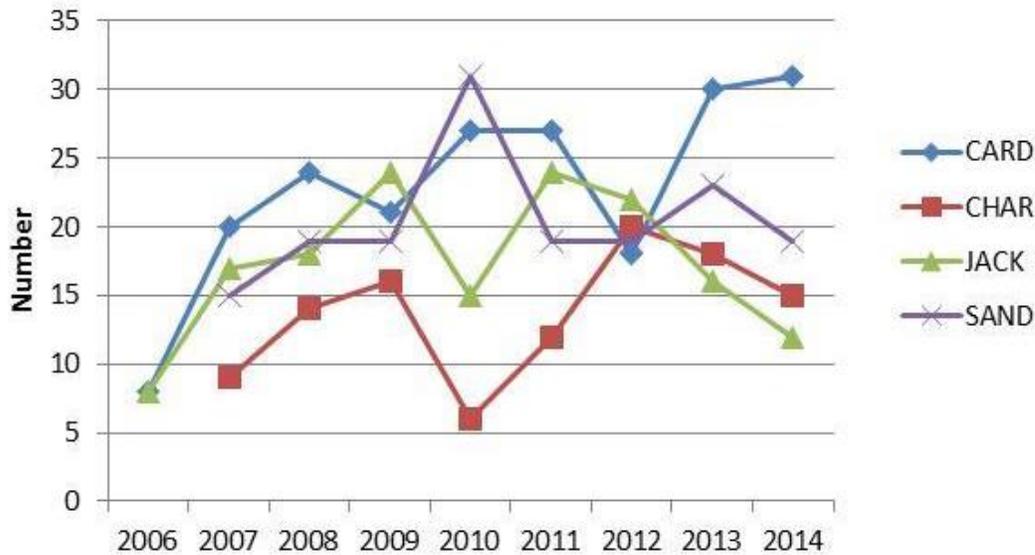


Figure 8. Individual grid densities, San Miguel Island, 2006-2014.

Table 4. Adult density estimates for small grids, San Miguel Island, 2014.

Monitoring Grid	Dates	Ind.	Density (foxes/km <sup>2</sup> )	SE	CV
Cardwell Point	8/27 - 8/31	29	19.1	3.826	0.57
Sandblast Pass	9/3 - 9/7	19	12.3	2.992	0.59
Jackass Flats	9/10 - 9/14	12	8.2	2.518	0.61
Charcoal Canyon	9/17 - 9/21	14	9.2	2.638	0.60
average			12.2		0.31

Table 5. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2006-2014; program Density) and from transect trapping (2005, MNKA), San Miguel Island.

	Adults					Total (adults plus pups)				
	n	N	SE	80% CI	$\lambda$	n	N	SE	80% CI	$\lambda$
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
2014	74	470	185.00	285-654	0.85	77	515	196.00	318-711	0.90

Table 6. Adult, pup and total captures on monitoring grids, San Miguel Island, 2009-2014.

	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
2014	180	3	183

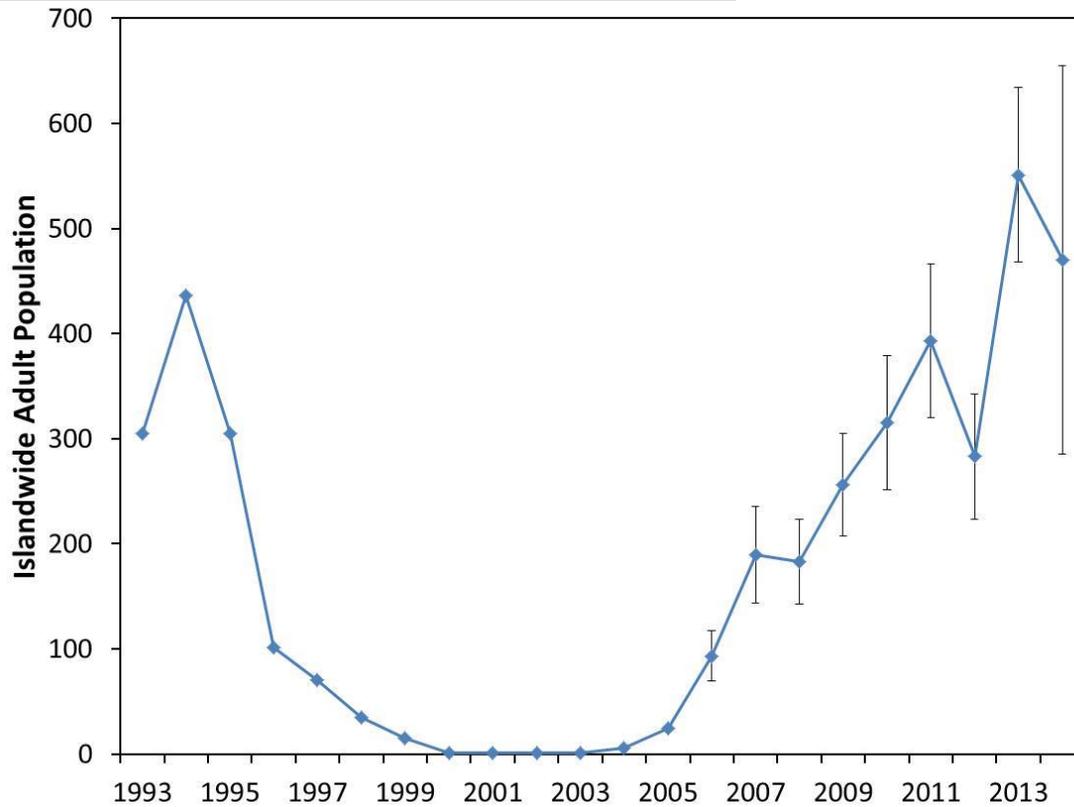


Figure 9. Islandwide adult population estimate, with 80% confidence interval, for San Miguel island foxes, from MNKA (2005) and grid-based density estimation (2006-2014).

As in 2013, very few pups were caught on the grids (Tables 5 and 6, Figs. 10 and 11). Only 3 were caught this year and last year, compared to 32 in 2012. Reproductive effort, as indicated by the ratio of pups produced per adult female, was among the lowest ever recorded (Fig. 10). The low reproductive effort coupled with declining survival (survival has declined since 2010; Fig. 5) 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. 11), 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. 12). 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, 2014.

	Male	Female	Total
Pups	1	2	3
Adults	44	29	73
Total	45	31	76

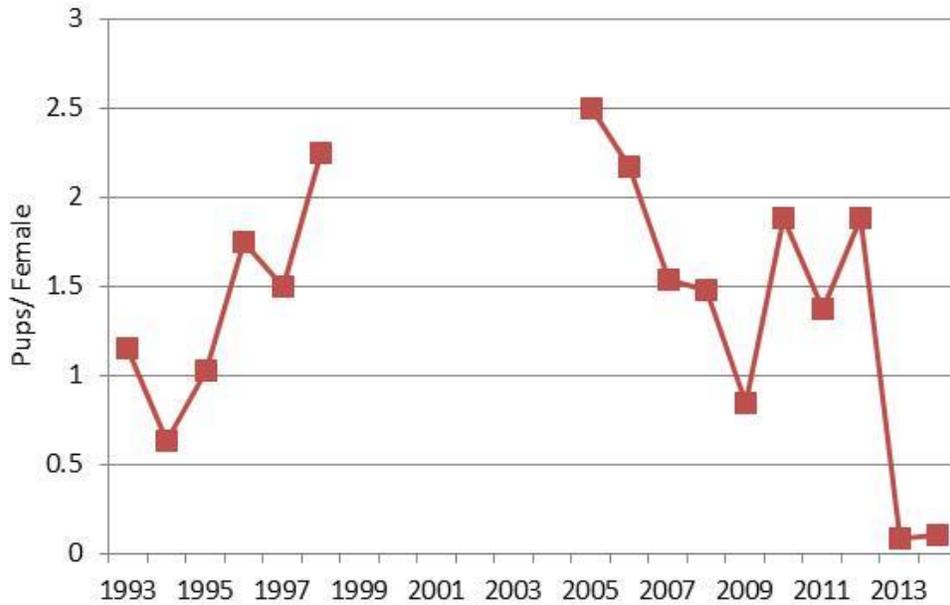


Figure 10. Reproductive effort as estimated by the ratio of pups to adult females, San Miguel Island, 1993-2014 (reproductive effort is not given for the years when foxes were solely in captivity, 1999-2003).

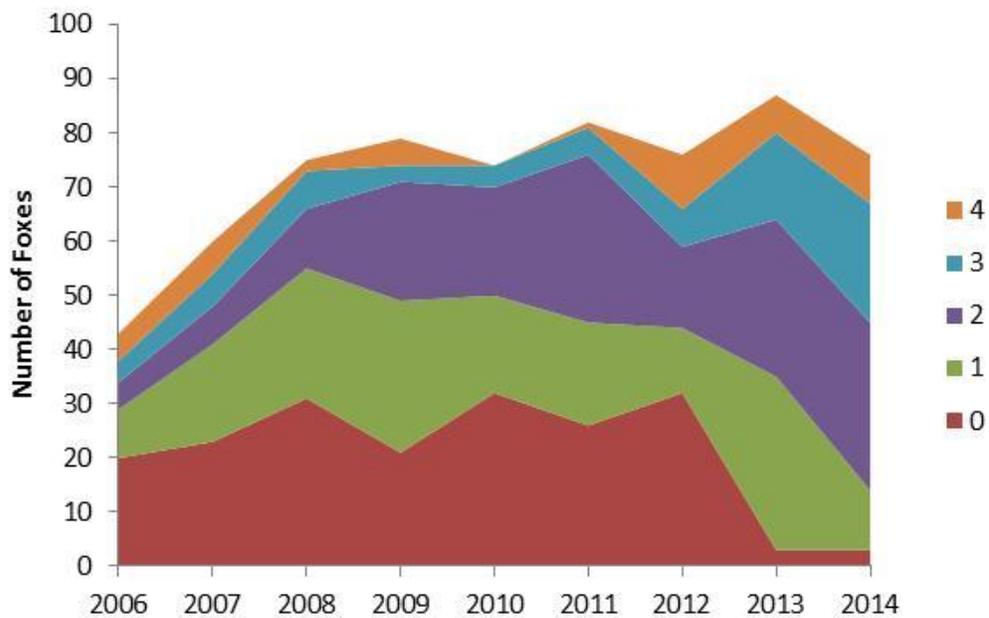


Figure 11. Total number and age class of individuals trapped on 4 grids, San Miguel Island, 2006-2014.

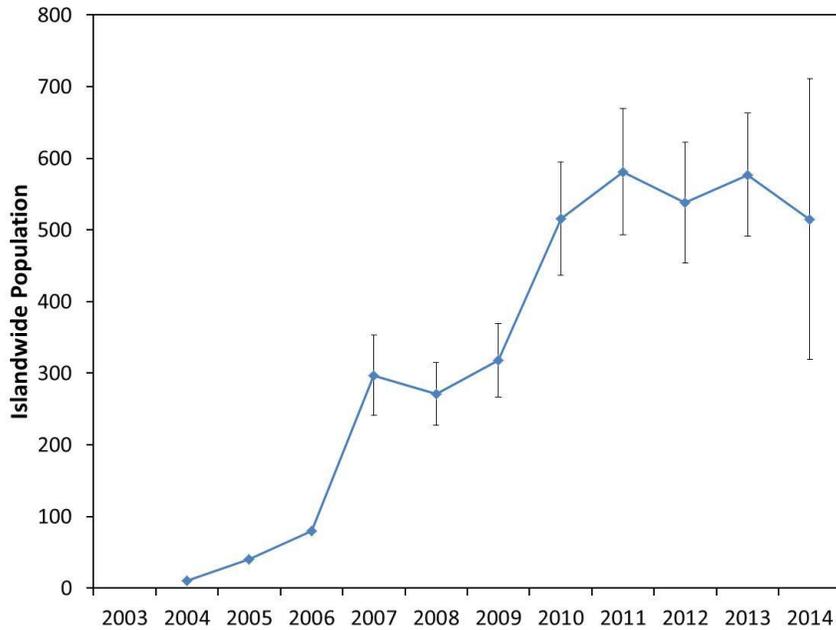


Figure 12. Estimated total (adult and pups) islandwide population, with 80% CI, San Miguel Island.

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 2008-2014 (Fig. 13) 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 island fox recovery plan (USFWS 2015a). The San Miguel population reached biological recovery in 2008, and the values for 2009-2014 indicate even greater probability of avoiding extinction. The San Miguel subspecies has returned to pre-decline population levels, and now has six “bubbles” below the 5% extinction isocline, and so can be considered biologically recovered.

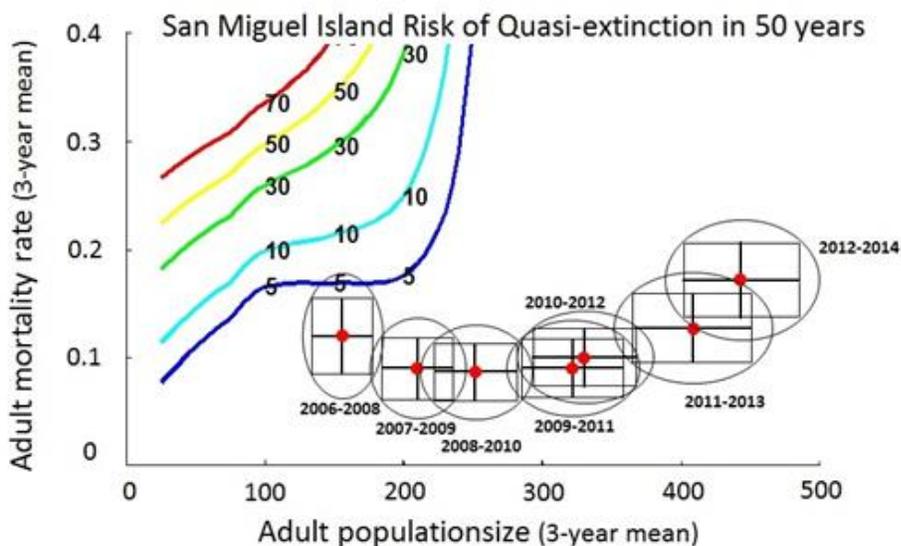


Figure 13. Extinction risk for San Miguel island foxes under 2006-2014 averages for adult mortality and population size.

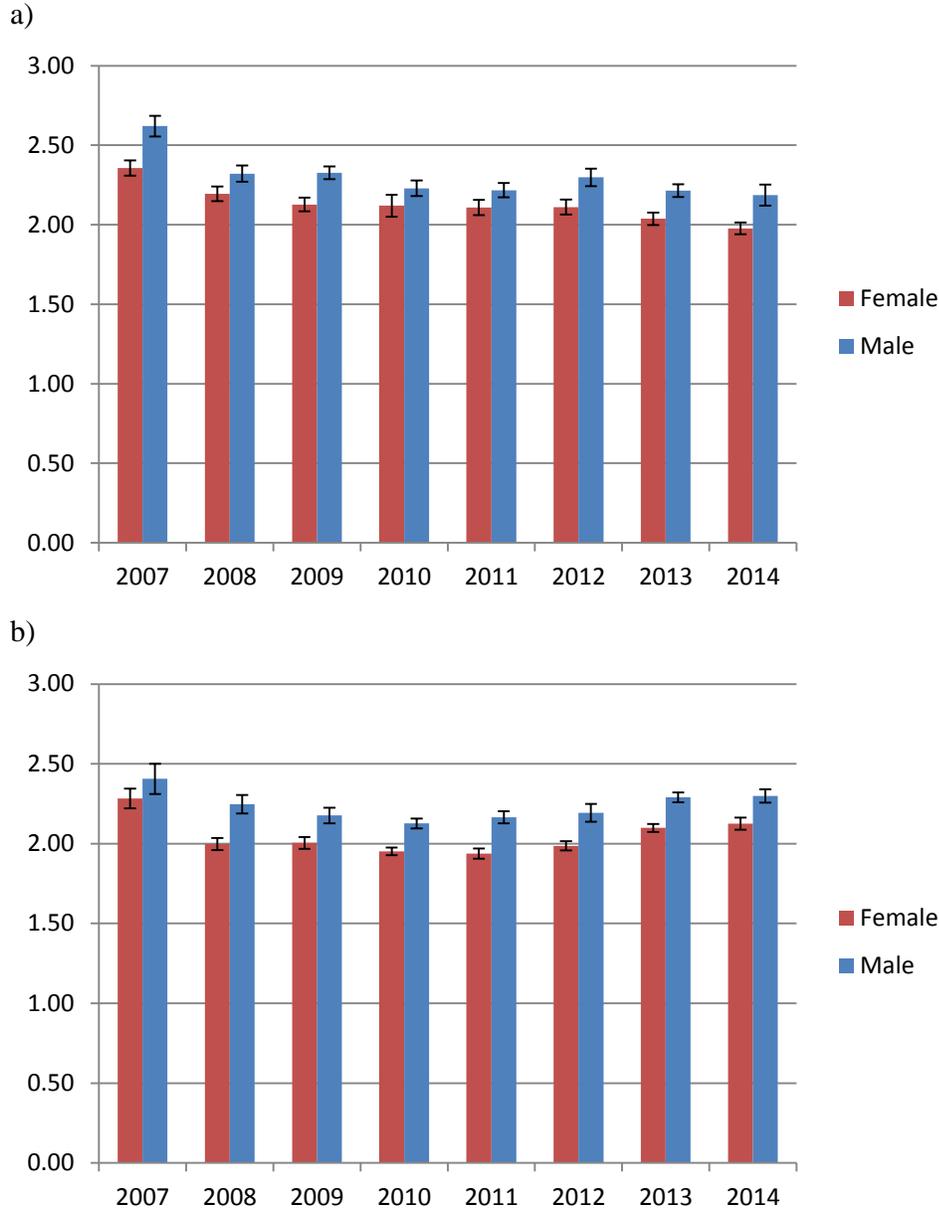


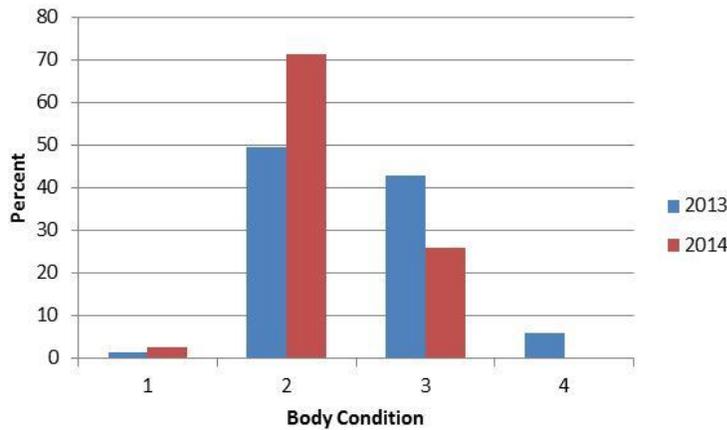
Figure 14. Average annual weights for adult island foxes on a) San Miguel and b) Santa Rosa Islands.

**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 drought is affecting island foxes on San Miguel, where island foxes are at carrying capacity and currently limited by resources. Adult weights on San Miguel in 2014 were very low, as in 2013 (Fig. 14a). Average female weight (1.98 kg) and average male weight (2.19) were the lowest since weights were first recorded in 2007. In contrast, adult weights on Santa Rosa, where foxes exist at much lower densities, were not low in 2014 (Fig. 14b). Male and female adult weights on Santa Rosa have increased annually since 2010.

The effects of the drought are also evident in body condition scores for captured foxes. Foxes are categorized as one of five body condition scores: 1 = emaciated, 2 = thin, 3 = optimal, 4 = fat, and 5 = obese. In 2014, foxes on both islands were thinner than they were in 2013 (Figure 15). On San Miguel, the proportion of thin foxes increased from 50% to 71%, and foxes in optimal condition decreased from 43% to 25%. On Santa Rosa, almost half the foxes (46%) were thin, and the proportion of foxes in optimal condition decreased from 60% to 44%. Overall, foxes were in better condition on Santa Rosa Island than on San Miguel in 2014, as they were the previous year (Coonan et al. 2014).

a)



b)

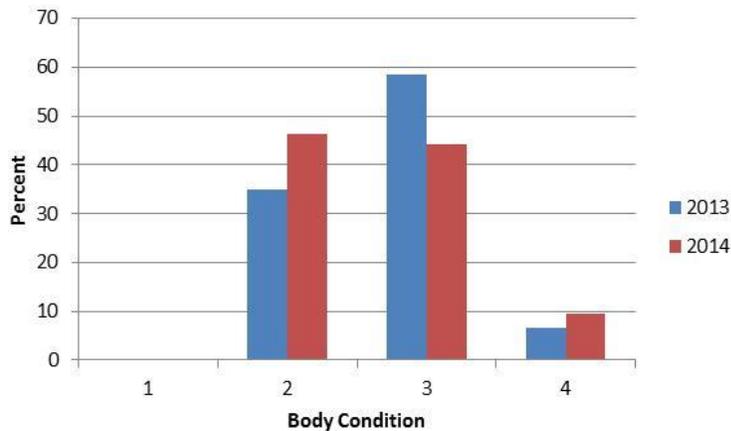


Figure 15. Body condition scores for island foxes on a) San Miguel and b) Santa Rosa in 2013 -2014 (1 = emaciated, 2 = thin, 3 = optimal, 4 = fat).

### ***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, 126 foxes were captured on San Miguel in 2014. Of those foxes, 105 were vaccinated against rabies, but none were vaccinated against distemper, since that vaccine was not available in 2014.

During the 2014 trapping season we maintained a sample of  $\geq 20$  unvaccinated, radiocollared juvenile foxes, to act as sentinel animals for detection of pathogen outbreaks. By the end of the year there were 24 sentinels on San Miguel and 35 sentinels on Santa Rosa. We collected blood samples for archiving and potentially for serology, scat for a St. Louis Zoo hormone study, and whiskers for a stable isotope study of fox diet (Table 7).

Table 7. Vaccinations administered and biological samples collected from San Miguel Island foxes and Santa Rosa Island foxes, 2014.

<b>Sampling type</b>	<b>San Miguel</b>	<b>Santa Rosa</b>
Total individuals	126	310
Total captures	288	698
Rabies vaccinations	105	147
Blood samples	135	337
Scat (hormone study)	70	67
Whiskers	137	327
Urine via cystocentesis	--	223

### ***Future Plans for San Miguel Island***

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 2015 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 2015 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 2014 we maintained a sample of 47-57 radiocollared foxes on Santa Rosa, and by the end of 2014 there were 57 radiocollared foxes on the island. Annual survival for Santa Rosa Island foxes in 2014 was 93% (92% CI = 89-97%) (Fig. 5). An annual survival rate of 80% is generally required for a stable or increasing fox population (Roemer et al. 2001). Five radiocollared foxes died in 2014, from unknown causes, but none from predation (i.e., there were none of the typical signs of golden eagle predation) (Table 8). The high survival rate stands in contrast to the lower rate on San Miguel.

Table 8. Island fox mortalities, Santa Rosa Island, 2014.

<b>PIT Tag</b>	<b>ID</b>	<b>Sex</b>	<b>Born</b>	<b>Age</b>	<b>Died</b>	<b>Mortality Cause</b>
60411	F170	F	Captive	6	1/30/2014	Unknown, no body fat, <i>Spirocerca</i>
36417	F154	F	Wild	6	5/20/2014	Unknown (deshicated)
B2D61	M31	M	Captive	8	6/1/2014	Unknown
F4F4E	F181	F	Wild	--	9/19/2014	Unknown (deshicated)
42558	M72	M	Wild	6	11/24/2014	Unknown

### ***Wild Population Abundance and Density***

Trapping was conducted on the 18 “ladder” grids (Fig. 3) from July through August. A total of 148 foxes (126 adults and 22 pups) were trapped on grids, and density estimates for the grids ranged from 1 – 5 foxes/km<sup>2</sup> (Table 9). When the average density of 3.8 foxes/km<sup>2</sup> was applied to the island area (216 km<sup>2</sup>), the estimated islandwide adult population was 826 foxes, with an 80% confidence interval of 675 - 1057 and a coefficient of variation of 0.14 (Table 9). Including pups in the analysis resulted in an islandwide population estimate of 877 foxes (80% CI = 759 -996; Table 10). The sex ratio favored males in both pups and adults (Table 11), while the ratio of pups to females was relatively low (0.42), as it was in 2013 (0.39).

Since the predation-fueled decline in 2010, Santa Rosa foxes increased dramatically, then growth slowed somewhat, likely due to the three years of extended drought (Fig. 16). The annual rate of increase, or lambda, was 1.12 in 2014 for both adults and for all foxes (adults and pups combined). Lambda was 1.45 in 2013. The Santa Rosa fox population is still 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.

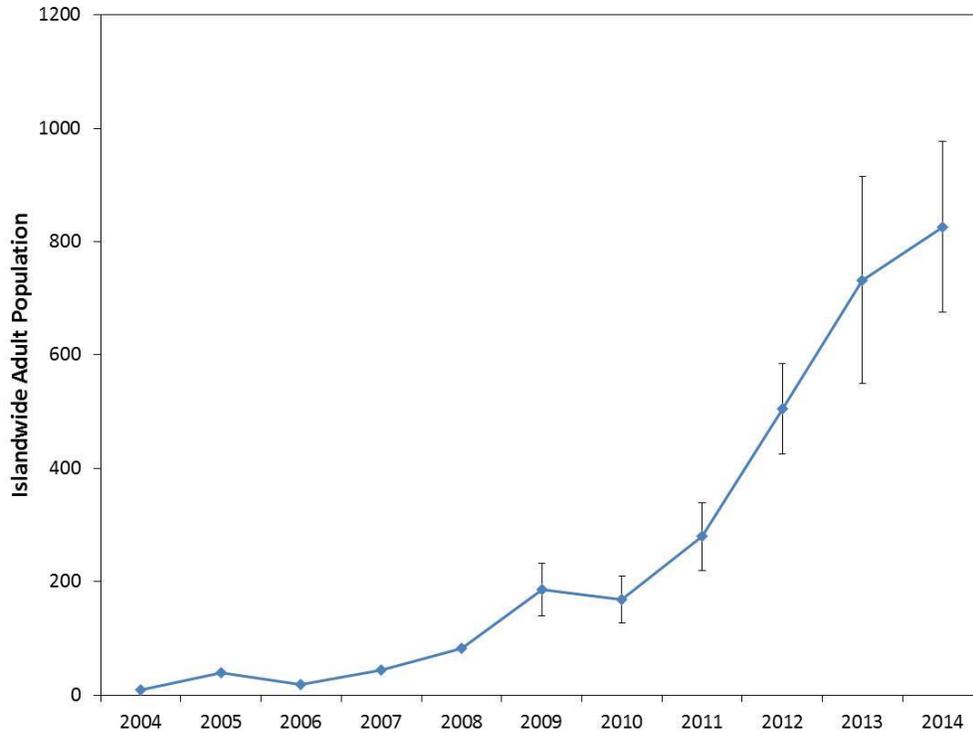


Figure 16. Islandwide adult population estimate, with 80% confidence interval, for Santa Rosa Island foxes, from MNKA (2004-2008) and grid-based density estimation (2009-2014, with 80% CI).

Table 9. Adult density estimates for ladder grids, Santa Rosa Island, 2014.

Grid	Dates	Indiv.	Density/km2	SE	CV
Lighthouse Road Grid	7/16 - 7/21	2	1.2	1.091	0.92
Signal Road Grid	7/16 - 7/21	10	5.3	2.889	0.54
Quemada Canyon Grid	7/23 - 7/28	8	4.2	2.417	0.58
Sierra Pablo Grid	7/23 - 7/28	8	4.4	2.502	0.57
Wreck Canyon Grid	7/23 - 7/28	9	4.8	2.673	0.56
Old Ranch Grid	7/23 - 7/28	6	3.3	2.036	0.62
Trancion Canyon Grid	7/30 - 8/4	8	4.3	2.468	0.57
Arlington Springs Grid	8/9 - 8/13	10	5.7	3.057	0.54
Arlington Canyon Grid	8/6 - 8/11	8	4.4	2.518	0.57
Burma Road Grid	8/6 - 8/11	5	2.7	1.778	0.66
Bee Canyon Grid	8/6 - 8/11	8	4.2	2.444	0.58
China Camp Grid	8/6 - 8/11	7	3.8	2.235	0.59
Pocket Field Grid	8/6 - 8/11	7	3.9	2.293	0.59
Verde Canyon Grid	8/13 - 8/18	8	4.3	2.454	0.57
Dry Canyon Grid	8/13 - 8/18	7	4.0	2.319	0.59
Johnson's Lee Grid	8/20 - 8/25	2	1.0	1.009	0.98
Telephone Road Grid	8/20 - 8/25	8	4.5	2.549	0.56
Carrington Point Grid	8/20 - 8/25	5	2.8	1.825	0.65
average			3.8		0.14

Table 10. Islandwide adult and total (adults plus pups) population estimates from grid trapping (2009-2014; program Density) and from transect trapping (2003-2008; MNKA), Santa Rosa Island.

	Adults					Total (adults plus pups)				
	n	N	SE	80% CI	$\lambda$	n	N	SE	80% CI	$\lambda$
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
2014	124	676	63.14	596-757	0.92	148	877	92.56	759-996	0.98

Table 11. Number of foxes captured, by age and sex, on 18 Santa Rosa grids, 2014.

	Male	Female	Total
Pups	14	11	25
Adults	66	57	123
Total	80	68	148

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 2006-2014 (Fig. 17) show that the Santa Rosa subspecies, for the second year, 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 2015a), the Santa Rosa subspecies will likely be considered biologically recovered in three years (2017).

### ***Vaccination of Wild Foxes, Establishment of Sentinel Animals and Collection of Biological 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, 310 foxes were captured on Santa Rosa in 2014. Of those foxes, 147 were vaccinated against rabies, but none were vaccinated against distemper, since that vaccine was not available in 2014.

During the 2014 trapping season we maintained a sample of  $\geq 20$  unvaccinated, radiocollared juvenile foxes, to act as sentinel animals for detection of pathogen outbreaks. At the end of 2014, there were 35 sentinel animals on Santa Rosa. We collected blood samples for archiving and potentially for serology, scat for a St. Louis Zoo hormone study, whiskers for a stable isotope study of fox diet, and urine samples for presence of *Leptospira* (Table 7).

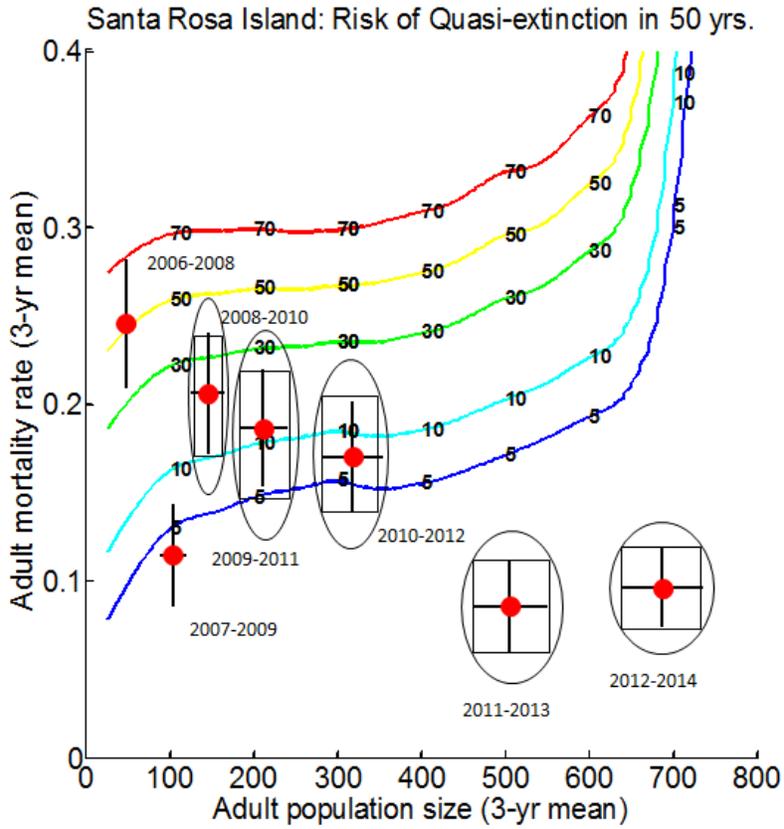


Figure 17. Extinction risk for Santa Rosa Island foxes under 2006-2014 averages for adult mortality and population size, 2006-2014.

### **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 2014 we captured 99 individual skunks, a decrease from the number we captured in 2012 (129). The number of individual skunks and density varied widely on the 18 ladder grids (Table 13), most likely due to variation in habitat type and/or quality among grids. Applying the average density of 6.6 skunks/km<sup>2</sup> to the island's area (216 km<sup>2</sup>) resulted in an islandwide density estimate of 1,415 skunks, with an 80% confidence interval of 1,188 – 1,643 and coefficient of variation of 0.13. With an islandwide estimate of 877 foxes, skunks were about 1.5 times as abundant as foxes (Table 12). However, skunk density estimates may be inflated due to the low recapture rate for skunks. Nonetheless, this is the second year that the number of skunks caught on the grid was less than the number of foxes. The skunk population has been fairly numerous, and stable, since 2009, but may now be decreasing.

Table 12. Density of island spotted skunks on ladder grids, Santa Rosa Island, 2014.

<b>Grid</b>	<b>Dates Trapped</b>	<b>Indiv.</b>	<b>Density Skunks/km<sup>2</sup></b>	<b>SE</b>	<b>CV</b>
Lighthouse Road Grid	7/16 -7/21	5	5.7	3.043	0.54
Signal Road Grid	7/16 -7/21	6	6.6	3.321	0.50
Quemada Canyon Grid	7/23 - 7/28	9	10.1	4.321	0.43
Sierra Pablo Grid	7/23 - 7/28	4	5.8	3.485	0.61
Wreck Canyon Grid	7/23 - 7/28	3	3.5	2.348	0.67
Old Ranch Grid	7/23 - 7/28	3	3.5	2.353	1.171
Trancion Canyon Grid	7/30 - 8/4	6	6.7	3.332	1.113
Arlington Springs Grid	8/9 - 8/13	4	5.2	3.054	0.59
Arlington Canyon Grid	8/6 - 8/11	7	8.0	3.727	0.47
Burma Road Grid	8/6 - 8/11	12	13.6	5.313	0.39
Bee Canyon Grid	8/6 - 8/11	4	4.6	2.716	0.59
China Camp Grid	8/6 - 8/11	4	5.7	3.469	0.61
Pocket Field Grid	8/6 - 8/11	4	5.1	3.038	0.59
Verde Canyon Grid	8/13 - 8/18	5	5.6	3.018	0.54
Dry Canyon Grid	8/13 - 8/18	1	1.6	2.019	1.30
Johnson's Lee Grid	8/20 - 8/25	7	7.7	3.648	0.47
Telephone Road Grid	8/20 - 8/25	5	6.3	3.415	0.54
Carrington Point Grid	8/20 - 8/25	10	12.6	5.238	0.42
average			6.6		0.13

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, 2009-2014.

	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)
214	149	99	877 (759 – 996)	1,415 (1,188 – 1,614)

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. 2014). Although one might thus expect skunks to decline in abundance as the Santa Rosa fox population recovers; this has not been the case until recently (2013-2014). The islandwide skunk population estimate increased from 2009-2012, and the number of individual skunks caught on grids did not decline until 2013 (Table 13). The relative decline in skunks recorded in 2013-2014 may be the beginning of the anticipated skunk population decline, as the fox population continues to increase.

***Future Plans for Santa Rosa Island***

Monitoring results from 2014 indicate a rapidly growing island fox population, with high survival, but still less than likely historic levels. Intensive island fox monitoring will continue in 2015. We will maintain a sample of >50 radiocollared foxes on the island, and we will conduct population monitoring in summer/fall 2015, 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, if the latter vaccine becomes available. Blood samples will be drawn from a subset of the island foxes we trap.

### Santa Cruz Island Campground Foxes

We conducted trapping at the Scorpion Campground, Santa Cruz Island, in July 2014 and in January 2015. Fox abundance (number of individuals captured) was greater in summer (32 foxes) than in winter (14) foxes, although there were no pups captured in summer (Fig. 18). This differs from previous trapping in summer 2012, when 10 pups were captured in the campground (Coonan et al. 2013). The lack of pups is similar to the 2014 age structure on San Miguel, and is perhaps due to the 3-year drought. Alternatively, high survival of juveniles from previous years may have discouraged foxes from reproducing in 2014. The bulk of foxes trapped in the campground were young adults (age class 1). Generally, more foxes use the campground in summer because human use is higher; during winter, half the campground is closed.

Foxes utilized the Lower Campground more than the Upper Campground in July 2014. Of the 32 individuals captured, 18 were captured solely in the Lower Campground, and 8 in the Upper, with an additional 6 foxes captured in both areas.

Scorpion Campground foxes were in relatively good body condition in summer 2014 (Fig. 19). More foxes were in body condition 3 (optimal) than in body condition 2 (thin), and a few were even classified as body condition 4 (fat). The range of body conditions was thus more similar to that on Santa Rosa than to that on San Miguel, where most foxes were thin in 2014. In January 2015 8 foxes were classified as optimal, and 3 as thin.

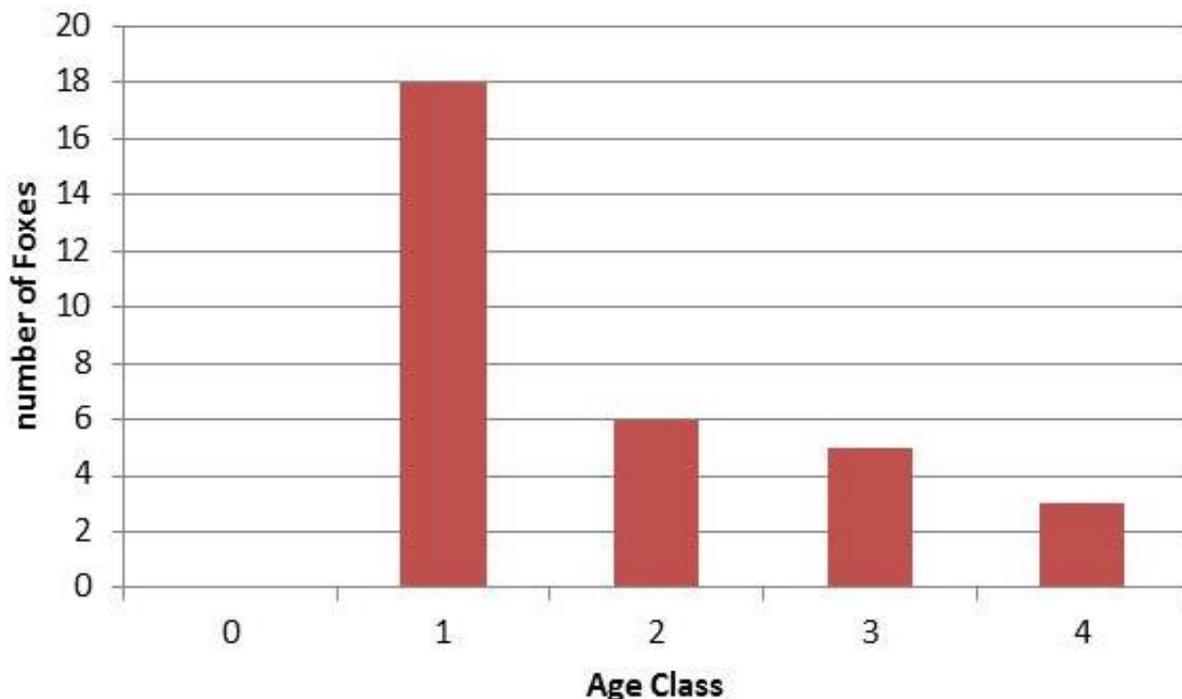


Figure 18. Age structure of foxes captured at the Scorpion Campground, Santa Cruz Island, July 2014.

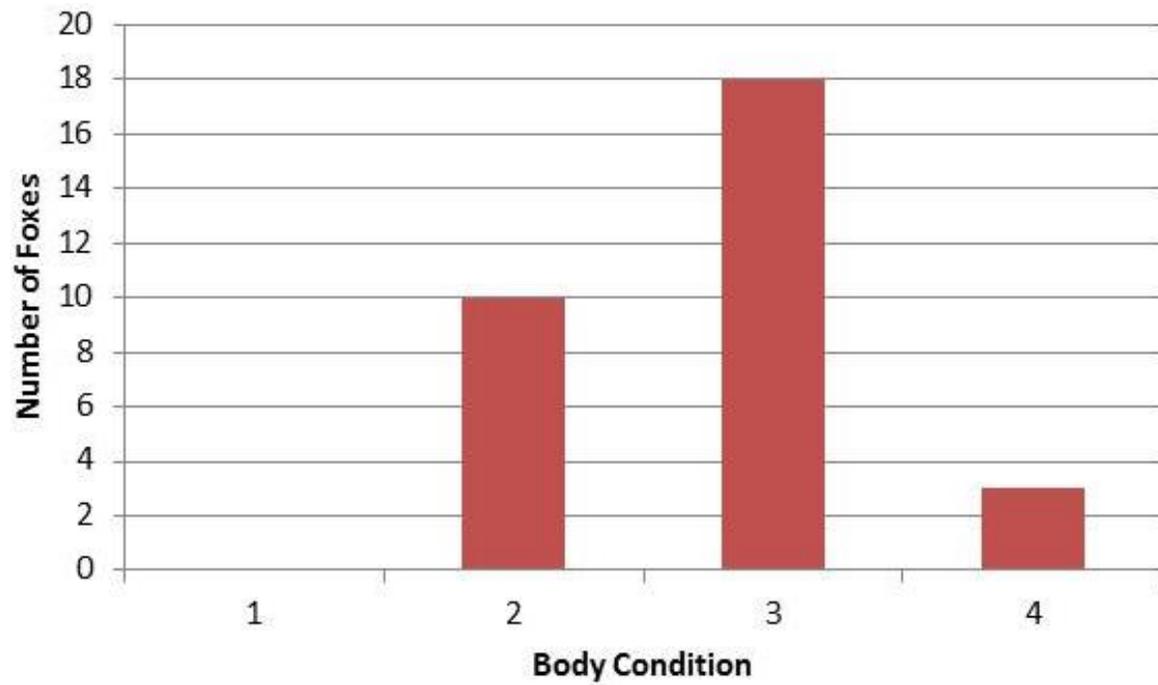


Figure 19. Body condition scores for foxes captured at the Scorpion Campground, Santa Cruz Island, July 2014 (1 = emaciated, 2 = thin, 3 = optimal, 4 = fat)

## Literature Cited

- Bakker, V.J. and D.F. Doak. 2009. Population viability management: ecological standards to guide adaptive management for rare species. *Frontiers in Ecology and the Environment* 7:158-165.
- Bakker, V.J., D.F. Doak, G.W. Roemer, D.K. Garcelon, T.J. Coonan, S.A. Morrison, C. Lynch, K. Ralls, and R. Shaw. 2009. Incorporating ecological drivers and uncertainty into a demographic viability analysis for the island fox. *Ecological Monographs* 79(1):77-108.
- Clifford, D. L., J. A. K. Mazet, E. J. Dubovi, D. K. Garcelon, T. J. Coonan, P. A. Conrad and L. Munson. 2006. Pathogen exposure in endangered island fox (*Urocyon littoralis*) populations: Implications for conservation management. *Biological Conservation* 131:230-243.
- Collins, P.W. 1993. Taxonomic and biogeographic relationships of the island fox (*Urocyon littoralis*) and gray fox (*U. cinereoargenteus*) from western North America. Pp. 351-390 in Hochberg, F.G., ed., *Third California Islands Symposium: Recent Advances in Research on the California Islands*. Santa Barbara Museum of Natural History, Santa Barbara, CA. Proceedings of the Third California Islands Symposium.
- Collins, P.W. and B.C. Latta. 2006. Nesting season diet of golden eagles on Santa Cruz and Santa Rosa Islands, Santa Barbara County, California. Santa Barbara Museum of Natural History Technical Reports – No. 3.
- Cooch, E, and G. White. 2006. Program MARK: a gentle introduction. 5th edition. Available online at <http://www.phidot.org/software/mark/docs/book/>.
- Coonan, T.J. 2013. Fifteenth annual meeting, island fox working group, summary report. unpublished report on file at headquarters, Channel Islands National Park. Available online at [http://www.mednscience.org/island\\_fox/meeting\\_reports](http://www.mednscience.org/island_fox/meeting_reports)
- Coonan, T.J. 2015. Annual report for island fox recovery actions conducted under Permit TE10857-2. Report submitted to Ventura Fish and Wildlife Office. On file at headquarters, Channel Islands National Park.
- Coonan, T.J., G. Austin, and C. Schwemm. 1998. Status and trend of island fox, San Miguel Island, Channel Islands National Park. Technical Report 98-01, National Park Service, Ventura, California. 27 pp.
- Coonan, T. J., A. Guglielmino and R. Shea. 2013. Island fox recovery program: Channel Islands National Park 2012 annual report. Natural Resource Report NPS/MEDN/NRR—2013/703. National Park Service, Fort Collins, Colorado.
- Coonan, T. J., A. Guglielmino and R. Shea. 2014. Island fox recovery program: Channel Islands National Park 2013 annual report. Natural Resource Report NPS/MEDN/NRR—2014/845.

- National Park Service, Fort Collins, Colorado.
- Coonan, T. J., K. McCurdy, K. A. Rutz, M. Dennis, S. Provinsky and S. Coppelli. 2005a. Island fox recovery program 2004 annual report. Technical Report 05-07. National Park Service. 63 pp.
- Coonan, T.J. and K. Rutz. 2001. Island fox captive breeding program 1999-2000 annual report. Technical Report 01-01. National Park Service, Ventura, California. 38 pp.
- Coonan, T.J., K. A. Rutz, K. McCurdy, D.K. Garcelon, B.C. Latta and L. Munson. 2004. Island fox recovery program, 2003 annual report. Technical Report 04-02. National Park Service, Ventura, California. 65 pp.
- Coonan, T.J. and C.A. Schwemm. 2009. Factors contributing to success of island fox reintroductions on San Miguel and Santa Rosa Islands, California. Pp. 363-376 in, Damiani, C.C and D.K. Garcelon, eds., Proceedings of the Seventh California Islands Symposium, Oxnard, California, February 5-8, 2008. Institute for Wildlife Studies, Arcata, California.
- Coonan, T.J., C.A. Schwemm and D.K. Garcelon. 2010. Decline and recovery of the island fox: a case history for population recovery. Cambridge University Press, UK. 212 pp.
- Coonan, T.J., C.A. Schwemm, G.W. Roemer, D.K. Garcelon, and L. Munson. 2005b. Decline of an island fox subspecies to near extinction. *Southwestern Naturalist* 50(1):32-41.
- Crooks, K.R. and D. Van Vuren. 2002. Update on the status of the island spotted skunk. Pp. 298-299 in, Browne, D.R, K.L. Mitchel and H.W. Chaney, eds., Proceedings of the Fifth California Islands Symposium, Volume 1. Santa Barbara Museum of Natural History, Santa Barbara, California.
- Cypher, B.L., A.Y. Madrid, C.L. Van Horn Job, E. Kelly, S.W.R. Harrison and T.L. Westall. 2014. Multi-population comparison of resource exploitation by island foxes: implications for conservation. *Global Ecology and Conservation* 2:255-266.
- Davis, G. E., K. R. Faulkner, and W. L. Halvorson. 1994. Ecological Monitoring in Channel Islands National Park, California. The Fourth California Islands Symposium: update on the Status of Resources. W. L. Halvorson and G. J. Maender, editors. Santa Barbara Museum of Natural History, Santa Barbara, CA.
- Efford, M. G., D. K. Dawson, and C. S. Robbins. 2004. DENSITY: software for analyzing capture-recapture data from passive detector arrays. *Animal Biodiversity and Conservation* 27 (1):217-228.
- Fellers, G.M., C.A. Drost and B.W. Arnold. 1988. Terrestrial vertebrates monitoring handbook. Unpublished report on file at park headquarters, Channel Islands National Park, Ventura, CA.
- Jones, K.L., D.H. Van Vuren, and K.R. Crooks. 2008. Sudden increase in a rare endemic carnivore:

- ecology of the island spotted skunk. *Journal of Mammalogy* 89:75-86.
- Latta, B.C., D. D. Driscoll, J. L. Linthicum, R. E. Jackman and G. Doney. 2005. Capture and translocation of golden eagles from the California Channel Islands to mitigate depredation of endemic island foxes. Pp. 341-350 in, Garcelon, D.K. and C. A. Schwemm, eds., *Proceedings of the Sixth California Islands Symposium*. National Park Service Technical Publication CHIS-05-01, Institute for Wildlife Studies, Arcata, California.
- Pollock, K. H., S. R. Winterstein and M. J. Conroy. 1989. Estimation and analysis of survival distributions for radio-tagged animals. *Biometrics* 45:99-109.
- Roemer, G.W. 1999. The ecology and conservation of the island fox (*Urocyon littoralis*). Ph. D. dissertation, University of California, Los Angeles, California. 229 pp.
- Roemer, G.W., T.J. Coonan, D.K. Garcelon, J. Bascompte and L. Laughrin. 2001. Feral pigs facilitate hyperpredation by golden eagles and indirectly cause the decline of the island fox. *Animal Conservation* 4:307-318.
- Roemer, G.W., C.J. Donlan and F. Courchamp. 2002. Golden eagles, feral pigs, and insular carnivores: how exotic species turn native predators into prey. *Proceedings of the National Academy of Sciences* 99:791-796.
- Roemer, G.W., D.K. Garcelon, T.J. Coonan, and C. Schwemm. 1994. The use of capture-recapture methods for estimating, monitoring, and conserving island fox populations. Pp. 387-400 in Halvorson, W.L. and G.J. Maender, eds. *The Fourth California Channel Islands Symposium: Update on the Status of Resources*. Santa Barbara Museum of Natural History, Santa Barbara, CA.
- Rubin, E. S., V. J. Bakker, M. G. Efford, B. S. Cohen, J. A. Stallcup, W. D. Spencer and S. A. Morrison. 2007. A population monitoring framework for five subspecies of island fox (*Urocyon littoralis*). Prepared by the Conservation Biology Institute and The Nature Conservancy for the Recovery Coordination Group of the Island Fox Integrated Recovery Team. U.S. Fish and Wildlife Service, Ventura, California.
- Timm, S.F., L. Munson, B.A. Summers, K.A. Terio, E.J. Dubovi, C.E. Rupprecht, S. Kapil and D.K. Garcelon. 2009. A suspected canine distemper epidemic as the cause of a catastrophic decline in Santa Catalina Island foxes (*Urocyon littoralis catalinae*). *Journal of Wildlife Diseases* 45:333-343.
- U.S. Fish and Wildlife Service. 2004. Listing of the San Miguel island fox, Santa Rosa island Fox, Santa Cruz island fox, and Santa Catalina island fox as endangered; final rule. *Federal Register* 69(44):10335-10353.
- U.S. Fish and Wildlife Service. 2015a. Recovery plan for four subspecies of island fox (*Urocyon*

*littoralis*). U.S. Fish and Wildlife Service, Sacramento, CA.

U.S. Fish and Wildlife Service. 2015b. Endangered and threatened wildlife and plant; recovery plan and initiation of status review for four subspecies of island fox (*Urocyon littoralis*). Federal Register 80 (45):12521-12522.

Wayne, R.K., S.B. George, D. Gilbert, P.W. Collins, S.D. Girman and N. Lehman. 1991. A morphologic and genetic study of the island fox, *Urocyon littoralis*. *Evolution* 45:1849-1868.

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

NPS 159/129984, September 2015

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



---

**Natural Resource Stewardship and Science**

1201 Oakridge Drive, Suite 150  
Fort Collins, CO 80525

[www.nature.nps.gov](http://www.nature.nps.gov)

**EXPERIENCE YOUR AMERICA™**