State of California
Natural Resources Agency
Department of Fish and Game
Wildlife Branch

Santa Cruz Island Fox Recovery Program
June 2009-December 2011

By
Christina Boser

Nongame Wildlife Program Report 2011-12

Final Report
To

State of California
Department of Fish and Game
South Coast Region
3883 Ruffin Road
San Diego, CA 92123

Santa Cruz Island Fox Recovery Program
June 2009-December 2011

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South Coast Region
Agreement No. P0982008

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ABSTRACT

In 2004, the Santa Cruz Island Fox (*Urocyon littoralis santacruzae)* was placed on the endangered species list after devastating predation rates by non-native golden eagles in the 1990's and early 2000's. In response to this crisis, island managers, government agencies, and research institutions implemented a comprehensive restoration program which helped to save the island fox from extinction. A Section 6 grant administered by the Department of Fish and Game (DFG) supported island fox conservation on Santa Cruz Island in 2009-2011. Using these funds, the Nature Conservancy (TNC) conducted island-wide census trapping, survival monitoring of a collared sub-sample, and disease management for the purpose of monitoring the recovery of the Santa Cruz Island fox.

We put in place golden eagle monitoring programs and conducted trapping operations to mitigate predation threats as needed. We produced educational materials on the island fox to distribute to the public. Island-wide census trapping was conducted using the ladder grid configuration (6 traps by 2 traps) recommended by Rubin et al. (2007). This trapping array allows us to calculate a statistically robust population estimate of non-pup foxes and island spotted skunks (*Spilogale gracilis amphiala*) using capture-recapture methods. Consistent with our protocol, the first 3 to 4 non-pup foxes captured in ladder grids were radio-collared for survival monitoring.

[1]Boser, C., 2011. Santa Cruz Island Fox Recovery Project, June 2009-December 2011. California Department of Fish and Game, Wildlife Branch, Nongame Wildlife Program Report 2011-12; South Coast Region Agreement No. P0982008; Sacramento, CA. 16 pp +app.

We also collared 10 young, unvaccinated foxes throughout the island which serve as "disease sentinels", and took blood for disease research. Following the recommendations by the veterinarian group, 100-150 foxes were vaccinated each year against rabies and canine distemper viruses within 2 core areas on the island (the central valley and isthmus) during ladder grid and roadside trapping. Island fox populations maintained a growth rate of $\lambda = 1.1$ during the term of the grant. The estimated fox population after the 2011 trapping regime was 1,350 foxes, and the population ended the grant period with an annual survival rate of 87.8% (SE=0.01). It is recommended that we continue to conduct annual population censuses and survival monitoring, continue to monitor for golden eagles, vaccinate for the most virulent of mainland diseases, and expand university sponsored research on the impacts of interspecific competition and climate change on island foxes.

INTRODUCTION

The endangered Santa Cruz Island fox (*Urocyon littoralis santacruzae*) is endemic to Santa Cruz Island and is one of six subspecies of island foxes that are found only on the California Channel Islands and nowhere else in the world. Historically, fox population estimates were as high as 3,000 on Santa Cruz Island, but by 2001 there were less than 100 individuals remaining in the wild. This catastrophic decline occurred when a small population of non-native golden eagles (*Aquila chrysaetos*) established on Santa Cruz Island in the 1990's. The eagles relied on the food resources provided by a robust population of feral pigs. The eagles also preyed upon the foxes, which had speciated without aerial predators, and thus were naïve to attacks by golden eagles. In less than a decade, a population of just a few dozen eagles was sufficient to drive the endemic island fox to near extinction on three northern Channel Islands.

In March 2004, the federal government listed four of the six subspecies as endangered due to the dramatic declines observed on Santa Cruz, Santa Rosa, San Miguel, and Santa Catalina Islands. Since that time, a number of steps have been taken to slow the decline and promote their survival. On Santa Catalina Island, an extensive vaccination program was initiated to address a disease epidemic that dramatically reduced populations on their east island. On Santa Cruz Island, The Nature Conservancy (TNC) initiated an on-island captive breeding program and wild fox monitoring program. The cause of the decline (predation of foxes by non-native golden eagles) was addressed through an ongoing live capture and translocation program funded by TNC, the National Park Service (NPS) and the Fish and Wildlife Service (FWS). Feral pigs were removed from Santa Cruz Island to reduce the food resources available to golden eagles.

Santa Cruz Island fox recovery has been a primary goal for TNC over the last eight years, and in that time considerable progress has been made. NPS and TNC have invested close to $1 million to translocate 32 adult golden eagles from the islands, with the last breeding pair of golden eagles removed in 2006. This tremendous accomplishment enabled us to successfully release the captive foxes, and in 2007 TNC concluded the captive breeding program.

The Channel Islands National Park *Recovery Strategy for Island Foxes (Urocyon littoralis) on the Northern Channel Islands* is used as the island fox recovery guide and currently under review at the Fish and Wildlife Service (FWS 2008). The Recovery Strategy was developed with extensive input from the professional conservation community and lists tasks needed for fox recovery. Work conducted under this grant addressed the following recovery tasks from that document:

1. Implement adaptive management program
    a. Implement annual population monitoring of each subspecies.
        i. Conduct transect trapping and radio telemetry monitoring.
2. Protect island foxes from canine diseases
    a. Vaccinate wild foxes against canine distemper virus, if required.
3. Implement other actions necessary for recovery
    a. Put in place a golden eagle management strategy and be prepared to respond to golden eagle predation of foxes.

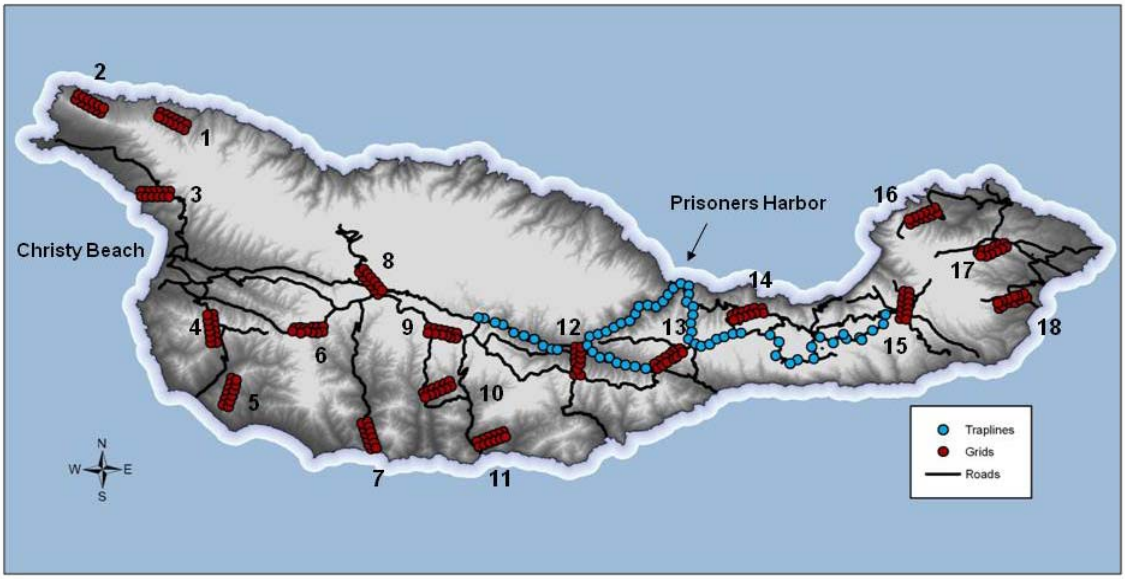
The 2008 Section 6 grant that funded this work helped to secure the investment that DFG, FWS, NPS, and TNC made in island fox recovery to date and reduced the likelihood of future population declines. The techniques implemented under this grant and described in the following sections have been largely successful. Between 2009 and 2011, the island-wide estimate of non-pup foxes increased from 798 to 950 individuals.

STUDY AREA

Santa Cruz Island, one of eight California Channel Islands, is located 30 km off the coast of California and lies within Santa Barbara County. The island is co-owned by TNC, which owns 76% of the island and NPS, which owns the remaining eastern portion. The 249 km^2 island is the largest of the Northern Channel Islands (Figure 1). It is approximately 34 km long east to west and 3 to 11 km wide from north to south (Schoenherr et al. 1999). The topography is dominated by an east to west running central valley with mountains on each side reaching a maximum elevation of 750 m (Laughrin 1973, Van Vuren and Coblentz 1987).

Island vegetation is made up of several general types of communities (chaparral, coastal sage scrub, grassland, and oak woodland) but can also be classified into much more detailed habitat categories (AIS 2007). The study area for this project included the entire island without regard to the NPS/TNC property line that crosses the island's isthmus (Figure 1). The diverse island habitat supports 480 native plant species, eight species of reptiles and amphibians, and four land mammals. The Santa Cruz Island harvest mouse (*Reithrodontomys megalotis santacruzae*) and the Santa Cruz Island deer mouse (*Peromyscus maniculatus santacruzae*) are prey of island foxes. The foxes also consume a variety of native plants and insects year round (Cypher 2009).

Figure 1. Santa Cruz Island fox trapping grid layout 2009-2011.



METHODS

Interagency Collaboration

During this grant period, TNC has worked closely with its partners to achieve successful results in endangered species monitoring and recovery. TNC's collaboration is achieved by data and method sharing, field data collection for studies requested by partner organizations, and presentations to inform and update partners about the island fox program. Specific information about these programs is included in the *Results* section.

Survival Monitoring

In order to monitor the island fox population, gain information on survival rates and detect prominent causes of death, TNC maintained at least 70 collared individuals with active radio collars year-round. This required us to collar between 20 and 60 individuals each year during annual trapping (see next section). It was important that collared individuals were statistically representative of the island population to gain the best estimate of island-wide survival and cause of death data. Therefore, we used captures at grids (already designed to measure the island population size with accuracy) to provide a sample of collared individuals proportionally distributed across the island. In addition, the Integrated Island Fox Recovery Team's Veterinary technical advisory group (TAG) recommended collaring young, unvaccinated foxes (disease sentinels), which would be unlikely to die except in the case of a disease outbreak. All deployed collars were new, weighed 39.5 grams, and had 18-27 month battery life transmitters (167.000 – 169.999 MHz) with mortality switches triggered after 12 hours of no movement (Holohil®, MI-2M).

Aerial survival monitoring of all collared foxes was conducted by TNC and a contractor 1-2 times weekly. When a mortality signal was detected, TNC personnel triangulated the

location of the carcass and collected it. Quick retrieval of fox carcasses allowed us to determine cause of death and increased our ability to react to emerging threats. All carcasses were sent to UC Davis for necropsy.

Population Trends

Indices of population abundance and distribution are required to adaptively manage a ecologically viable population of island foxes. In 2009-2011, TNC implemented an 18-grid trapping design (based on Scenario B, Figure 3 in Rubin et al. 2007). Trapping grids were in a "ladder" configuration of 2 x 6 traps, each spaced 200 m apart and trapped for six consecutive nights. Their locations were predetermined by a geographic information system (GIS) analysis, described in detail in Rubin et al. (2007). The grid pattern and placement was designed to provide a statistically robust estimate of island fox density (to be calculated in Program Density and Program R; Efford 2004). To more efficiently manage annual trapping, TNC permanently deployed traps in the field, which were re-conditioned at the start of each trapping periods and fixed shut after the trapping session concluded. TNC secured permission and a research permit (CHIS-2009-SCI-0012) from NPS to set up the five grids located on NPS property. Every trap at grids on NPS property had an informational sign attached, and on TNC property the trap closest to a road was signed.

Grid trapping began on June 30 and was completed by October 1 in each year. These dates were selected because pups are out of dens by July and are being weaned, but unlikely to disperse from natal territories prior to October. Trapping during the summer months increases the accuracy of the census by reducing the likelihood of foxes dispersing between grids. Grids were baited with dry cat food and loganberry paste lure and were set open for six consecutive nights. Traps were checked every morning between sunrise and six hours after sunrise. All trapping activities followed the Terms and Conditions outlined in TNC's state and federal permits for island foxes and island spotted skunks.

Island Fox Handling

Foxes captured during grid trapping were scanned to determine if they had been tagged in a previous year. The capture status (new, previously tagged, or recaptured during a grid) was recorded for every capture. Those individuals not tagged were pit tagged beneath the scruff of the neck using a single-use passive integrated transponder syringe (Biomark® TX1440). New and previously tagged foxes were weighed and aged (via tooth wear), and parasite load, body condition, and reproductive condition were assessed. Staff treated minor injuries with first aid if needed. Specific individuals were radio collared, vaccinated against rabies and canine distemper viruses, or bled. Fox handling methods were consistent for grid and roadside captures.

Island Spotted Skunk Handling

Similar to foxes, skunks captured at grids were initially scanned to determine capture status. Those not previously tagged were given pit tags using the same method as for foxes. We checked gender and aged skunks as either adults or juveniles based on body size.

Golden Eagle Translocation

TNC has undertaken a multi-year effort to live-capture all golden eagles and transfer them off the northern Channel Islands. These birds have become increasingly elusive as the population has been reduced, and golden eagle sightings are now very infrequent and unpredictable. For the duration of the grant period, TNC maintained contracts with two entities carrying permits to search for, trap and translocate golden eagles off the northern Channel Islands. We maintained close coordination with DFG, FWS, and our contractors, Native Range Inc, and the Institute for Wildlife Studies to renew the necessary permits to survey and capture golden eagles when appropriate. If radio monitoring data of foxes indicated that five or more collared foxes were predated upon by golden eagles within a four-week period, then TNC worked with these entities to implement a golden eagle trapping and translocation regime. Methods of trapping could include bow-netting or net-gunning of golden eagles. In the event that an eagle was captured, TNC would translocate the animal to northern California and continue to survey the area for a nest and possible mate.

Disease Risk Management

Vaccination of at least 80 foxes against rabies and canine distemper viruses within the core areas (central valley and isthmus) was recommended by TAG and required in the Section 6 grant agreement. To be successful, this required a focused trapping effort and thus we conducted roadside trapping along with grid trapping to maximize captures. The number of traps set and the number of trap nights varied among roadside traplines. Traps were placed from 250 to 350 meters apart in vegetation that would shield traps from the sun and wind. All trap site coordinates were recorded using a global positioning system (GPS) unit, entered in the trap locations spreadsheet, and flagged. Vaccination was also conducted opportunistically during grid trapping.

We vaccinated most adult foxes captured within the core areas to increase the concentration of protected animals within those cores. Pups captured within the core areas were not vaccinated until mid-July, as per recommendations made by TAG. The canine distemper vaccine (Merial's Purevax® Ferret Distemper) was administered to foxes by intramuscular injection in the left hip. The rabies vaccine (Merial's Imrab 3®) was administered with a subcutaneous injection in the right hip. Foxes were vaccinated against both viruses and were held for five minutes following the injections to monitor for any adverse reactions to the vaccine.

The collection of biological samples that can be used for disease research allows TNC to monitor for a variety of diseases and further protect foxes from the risk of introduced diseases. Following the recommendations of TAG, we prioritized our blood sample collection from individuals that had never been previously vaccinated.

On average, we collected 5cc of blood from selected individuals, which provided at least two 1-ml serum samples and one vial holding a red blood cell (RBC) clot. We used 20- and 22-gauge 1.5" needles on 10 ml syringes to collect samples from the jugular vein or artery from foxes wearing muzzles that doubled as blindfolds. Samples were stored in a

cooler with ice packs while in the field and then refrigerated. On the same day as collection, we processed samples using a centrifuge to separate serum from red blood cells. We used plastic pipettes to transfer each serum or RBC sample into micro vials. Samples were labeled with animal id, collection date, and sample type. We froze samples immediately following processing. On the recommendation of TAG, blood samples from 2008-2010 were sent to Cornell Veterinary Labs to determine titer levels for common viruses (canine adenovirus, canine coronavirus, canine distemper virus, canine herpesvirus, canine parvovirus). These data will be compared to data taken by D. Clifford in 2003.

RESULTS

Interagency Collaboration

For the duration of this grant, TNC maintained close collaboration with research institutions UC Davis Wildlife Health Center, California State University-Stanislaus Endangered Species Recovery Program, St. Louis Zoological Society, and Colorado State University (CSU). We provided 50 fox serum samples to the UC Davis Wildlife Health Center for their study on West Nile virus in the Channel Islands. All samples tested negative for West Nile virus. We collected scat samples for Principal Investigator, Brian Cypher, to support his research on island fox diet and prey items (Cypher 2009). In 2009, the St. Louis Zoo, headed by Cheri Asa, conducted a research study examining cortisol levels in wild island foxes via scat samples. Dr. Asa required scats that had been deposited within 24 hours and then frozen immediately upon collection. We collected 11 samples for this study. To be sure we only collected fresh scats, we cleared collection areas and grounds of all scats of unknown age prior to collection. Then, each morning we collected new scats left the night before.

In 2010, we entered into a corporative agreement with Colorado State University (CSU) and Principal Investigator Kevin Crooks. Dr. Crooks has hired a Ph.D student to research interactions between the Santa Cruz Island fox and island spotted skunk. This research collaboration built on an existing project with CSU researching the island scrub jay. Data such as scrub jay genetic samples (feathers, N=11) were collected during fox trapping and shared with jay researchers.

We have also collaborated on management actions with the land managers of the Channel Islands such as the Catalina Island Conservancy, the National Park Service (NPS), and the US Navy. We have shared our management results and analysis techniques with these land managers in an annual paper we distribute during the fox meetings in Ventura, CA. A copy of this paper has been provided to DFG each year.

In 2011, NPS indicated that the island foxes at the Scorpion campgrounds on Santa Cruz Island were becoming a disruption to campers. They raised concerns about the health and safety of the foxes and the public due to a number of campers feeding the foxes, both intentionally and unintentionally. They decided to conduct trapping in October of 2011 and again in February of 2012 to determine how many foxes were affected by the campsites, and whether the foxes remained in the area during seasons of low visitation.

TNC supported this study by sharing available data on the east end foxes and providing the required equipment (e.g., PIT tags) to NPS staffers.

Survival Monitoring

To determine the magnitude of potential threats to the recovery of the island fox, it is necessary to monitor the population for survival rate and primary cause of death. In order to detect whether cause of death was disease, golden eagle predation or some other cause, carcasses must be collected prior to decomposition and a necropsy performed. Thus, TNC radio-collared a representative population of foxes and frequently monitored those animals to determine when and how they died. Over the course of the 3 year grant an average of 39% of our collared population were considered age class 1 individuals, 36% were age class 2 individuals, 16% were age class 3 individuals and 9% were age class 4 individuals.

Between June 2009 and November 2011, we monitored foxes 123 times from the air and on average located 92% of the foxes with functioning radio collars. We located 13 collared fox mortalities. Four of those foxes were killed by golden eagles, and nine foxes died of unknown causes and will be necropsied by staff at UC Davis (Table 1). In a few cases, the fox carcasses were not able to be retrieved immediately due to poor weather conditions, and thus a cause of death will not be able to be determined by UC Davis. Fox survival rates were calculated using radio monitoring data. Annual survival rates are calculated between May 1 and April 30 of a given year. Estimated non-pup survival was 96% (SE = 0.01) in 2008-2009 and 2009-2010. In 2010-2011, the non-pup survival rate was estimated at 87.8% (SE = 0.01; V. Bakker).

Table 1. Fox mortalities June 2009-November 2011.

Fox ID	UTM E	UTM N	Date	Cause of death
M390	240092	3764240	7/3/2009	Unknown- necropsy pending
M264	260639	3766625	12/15/2009	Unknown- necropsy pending
F21	254373	3765169	12/27/2009	Unknown- necropsy pending
F301	243852	3766109	5/26/2010	Golden Eagle
M288	243200	3764189	5/26/2010	Golden Eagle
F130	263298	3767816	8/3/2010	Unknown- necropsy pending
M339	236534	3764079	10/10/2010	Golden Eagle
M259	256107	3785681	12/16/2010	Unknown- necropsy pending
F407	251943	3764760	12/16/2010	Unknown- necropsy pending
M37	243933	3762852	12/24/2010	Unknown- necropsy pending
M468	248757	3762277	1/28/2011	Golden Eagle
M401	253720	37677320	3/18/2011	Unknown- necropsy pending
M494	254888	37766278	9/23/2011	Unknown- necropsy pending

Population Trends

Annual island-wide trapping on standardized sampling grids was conducted in 2009-2011 following the methodology described in the preceding section. Fox capture success for varied greatly by grid and between years (Table 2). In 2009, 147 individuals were captured on the grids, in 2010, we captured 164 foxes, and in 2011, we captured 165 foxes. Young-of-the-year capture success averaged approximately 35% of total trap population over the three trapping years (Table 2).

Table 2. Island fox captures on grids, 2009-2011.

Grid	Location	2011: Individual Foxes (Pups)	2010: Individual Foxes (Pups)	2009: Individual Foxes (Pups)
MG1	North Shore	4 (1)	2 (0)	0 (0)
MG2	West End	4 (2)	6 (1)	3 (1)
MG3	Black Canyon	5 (4)	2 (0)	1 (0)
MG4	Pozo	8 (0)	10 (4)	8 (2)
MG5	Johnson	8 (0)	11 (2)	9 (5)
MG6	Sauces	13 (5)	9 (2)	7 (3)
MG7	Laguna	6 (2)	8 (4)	5 (3)
MG8	Centinela	7 (3)	5 (0)	7 (3)
MG9	Ridge Road	14 (6)	15 (6)	12 (6)
MG10	Lower Horqueta	9 (5)	6 (2)	9 (4)
MG11	Justiano	11 (6)	8 (2)	7 (1)
MG12	Main Ranch	15 (1)	13 (5)	14 (2)
MG13	Valley Peak	13 (4)	14 (3)	20 (7)
MG14	Del Norte	14 (5)	17 (4)	14 (8)
MG15	Loma Pelona	14 (3)	16 (6)	6 (1)
MG16	Potato	7 (0)	5 (2)	3 (0)
MG17	Scorpion	6 (2)	9 (2)	11 (1)
MG18	Yellowbanks	7 (2)	9 (0)	10 (4)

Like foxes, skunk capture success varied by grid, and generally decreased from year to year (Table 3). Individual captures at each grid ranged from zero to 18. Total number of individual skunks captured ranged from 116 in 2009, to 63 in 2010, and 34 in 2011.

Table 3. Island skunk captures on grids, 2009-2011.

Grids	Location	2011: Individual Skunks (New)	2010: Individual Skunks (New)	2009: Individual Skunks (New)
MG1	North Shore	2 (1)	5 (2)	6 (3)
MG2	West End	1 (1)	4 (3)	2 (1)
MG3	Black Canyon	0 (0)	2 (0)	18 (7)
MG4	Pozo	1 (0)	8 (3)	17 (11)
MG5	Johnson	1 (0)	1 (0)	9 (8)
MG6	Sauces	2 (2)	5 (2)	7 (5)
MG7	Laguna	4 (3)	1 (0)	4 (4)
MG8	Centinela	6 (3)	7 (1)	11 (5)
MG9	Ridge Road	2 (2)	2 (0)	6 (5)
MG10	Lower Horqueta	5 (3)	5 (3)	6 (6)
MG11	Justiano	1 (0)	0 (0)	4 (1)
MG12	Main Ranch	4 (1)	1 (1)	6 (3)
MG13	Valley Peak	1 (1)	1 (1)	2 (1)
MG14	Del Norte	2 (1)	7 (5)	5 (3)
MG15	Loma Pelona	4 (0)	7 (6)	8 (6)
MG16	Potato	2 (1)	5 (4)	14 (12)
MG17	Grid	6 (4)	12 (5)	12 (10)
MG18	Yellowbanks	4 (2)	4 (1)	6 (4)

Data Analysis

During the grant period, peer-reviewed population and demographic publications have been advanced by our radio-collaring effort, the island-wide population census, and the marking of captured individuals with PIT tags. Specifically authors D.F. Doak, V.J. Bakker, and W. Vickers are submitting their paper, *Assessing alternative strategies to minimize disease threats to an endangered carnivore using population viability criteria,* to the Proceedings of the National Academy of Sciences. This paper created an epidemic model linked to a previously published demographic population model, which was used to assess the efficacy of a vaccinated core for the management of a rabies epidemic in island fox populations.

These field data also allow our partners (e.g., Colorado State University and V. Bakker of James Madison University) to estimate demographic parameters, habitat use, and activity patterns for our management program. In 2010, V. Bakker used trapping data to yield an island-wide population estimate of 918 non-pup foxes on Santa Cruz Island. This was a 13% increase over her 2009 estimate (N= 798). The 2011 island-wide estimate of non-pup foxes is 950 individuals. The relatively modest increase is likely due to a lower

survival rate in 2010-2011 (87%) in comparison with 2008-2009 and 2009-2010 annual survival estimates of 96%.

TNC began collaborating with Colorado State University (CSU) in 2010 to fulfill the grant requirement of additional academic island fox research. CSU hired a Ph.D student in 2010 and is researching questions of island fox and skunk demographics, habitat use, and activity patterns. This research is expected to conclude in 2015.

Golden Eagle Translocation

Despite frequent monitoring (as described in the *Survival Monitoring* section), TNC never recorded five or more collared foxes predated by golden eagles within a four-week period. In fact, we documented only four golden eagle predation mortalities within the 2.5-year grant period.

In 2010, there were a number of golden eagle predation mortalities on neighboring Santa Rosa Island and their fox annual survival rate plummeted to 70%. On Santa Cruz Island, we detected two foxes killed by golden eagles in late May 2010. In response to this emerging threat on the northern Channel Islands, we worked with the Institute for Wildlife Studies to implement a trapping regime in early July 2010. If successful, we would have translocated any trapped golden eagle off the islands and into northern California. However, after several days of attempted bow-net trapping, the effort was concluded without sighting a golden eagle. No other golden eagle trapping attempts were made by TNC during the grant period.

Disease Risk Management

Following the recommendations of the TAG made in June 2007, and the objectives TNC set down in the grant agreement, a total of 100 foxes per year were vaccinated for rabies and canine distemper virus (CDV) in 2009 and 2010. In 2011, we increased the number of distemper vaccinates to 150. Previous research has indicated that a canine distemper virus outbreak could be the most severe threat to the island fox population. Our trapping and vaccine strategy already maximizes opportunities to booster foxes, but an increasing fox population makes it more difficult to recapture the same foxes for an annual booster, without increasing the number of vaccines given. With a dedicated trapping effort in 2009-2011, many previously vaccinated animals received boosters. Most vaccinated animals were captured within the core vaccination areas of the central valley isthmus. We expect that by increasing the number of vaccines administered in 2011, we will be able to more easily booster animals in 2012.

We collected blood samples from individuals during grid and roadside trapping to test for disease titers. In 2009, we bled 32 foxes, in 2010, we bled 25 foxes, and in 2011, we bled 112 foxes. At least 1 mL of serum was collected from each of these individuals. We prioritized foxes for bleeding based on TAG recommendations; thus, the majority of the samples were collected from foxes not previously vaccinated. Since most roadside traps were located within the core vaccination areas (where there are a greater proportion of previously vaccinated foxes), we collected more samples from grids located outside of the core vaccination areas.

TNC has produced two educational materials on the island fox, the Santa Cruz Island timeline and Santa Cruz Island field guide (Appendix 1). TNC staffers have given presentations about the island fox to the Rotary Club, an NPS concessionaire (Island Packers), the County Museum of Ventura and at the Island Fox meetings in 2009-2011. We have produced an island fox mount which is now on permanent loan to the County Museum of Ventura and is on display in the Chumash Exhibit. TNC staff led training with the museum education staff and guides to inform those individuals about the island fox, their inclusion on the endangered species list, and subsequent recovery trajectory. We produced educational signs which described threats to the island fox, the recovery effort, and ways that visitors can protect the fox. These signs are displayed at three popular anchorages (Prisoners, Pelican and Coches Prietos) around the island (Appendix 1).

DISCUSSION

Critical to island fox recovery on Santa Cruz Island is a robust monitoring program that can quickly detect emerging threats. Although foxes now have a lower risk of extinction than in 2004, those same threats that caused the original population decline still remain. Thus, annual population surveys, radio-monitoring, and golden eagle translocation are still critical to fox recovery. Disease risk management further ensures the long-term protection of foxes from new epidemics. Further research into island fox behavior and management techniques will enhance our understanding of this keystone island species and prepare us for management after delisting.

Mark-recapture data was used to choose the best population models that explained the relative influences of factors such as habitat and interspecific interactions on population density (V. Bakker). These models indicate that the fox population on Santa Cruz Island increased at a steady rate of approximately $\lambda = 1.1$ from 2008 to 2010. Capture data from 2009 and 2010 detected a dynamic between skunk and fox densities such that skunk and fox captures were inversely related (Bakker 2009[b]). Average skunk capture success on trapping grids was lower than average fox capture success in all years, and is decreasing on most grids. Skunk trapping success is still much higher than reported in the late 1960's and early 1970's and 1990's, prior to the fox extinction crisis (Laughrin 1973, K. Crooks personal communication 2011).

The project objectives of this grant were two-fold:

- Collect and analyze survival rate, population trend and mortality data via radio-tracking and mark-recapture efforts to determine the threats to the fox population;
- Increase fox survival by reducing the major threats posed by golden eagle predation and disease introduction.

We accomplished three trapping sessions during the course of the grant (2009-2011) and the results of these sessions were presented in the preceding section. These sessions and the subsequent radio monitoring data collected on a weekly basis allowed us to analyze

and present the survival rates, population trends, and mortality data described in the *Results* section. After analyzing mortality data collected in 2009-2011, we determined that golden eagles are still a threat to the island fox; however, the foxes did not experience debilitating predation during the term of the grant. Although no collared foxes on Santa Cruz Island died of diseases in 2009-2011, disease risk management remains a high priority because modeling research and data on island fox titers show that island foxes are very susceptible to mainland diseases such as CDV.

Our second objective, to increase fox survival by reducing major threats, was achieved through a combination of golden eagle monitoring, fox vaccination, and fox biological sample collection and testing. Fortunately we did not locate any nesting golden eagles on Santa Cruz Island in 2009-2011. We expect that golden eagles will be further deterred from nesting on the Channel Islands when elk and deer are removed from Santa Rosa Island in December 2011. Our best defense against the threat of disease remains vaccination of a core population of foxes, as recommended by TAG. We recommend continuing this program by vaccinating 150 foxes each year for the next five years. The introduction of a virulent mainland disease will always be possible as visitation to the Channel Islands increases. As a direct result of more than a decade of intensive threat management, island fox survival rates increased during the grant period from an average of 80% over the previous 3 years (2006-2008), to 93% (2009-2011).

This fox recovery project, created by a collaborative effort among TNC, university researchers, and agencies such as DFG, may be used as a model endangered species recovery strategy. The program is structured as a long-term recovery project, which addresses critical data requirements meant to guide management actions, addresses emerging threats, while remaining functionally efficient and scalable.

RECOMMENDATIONS

We highly recommend continuing the population censuses and survival monitoring strategies described in Rubin et al. (2007). The quality of data collected from the trapping grids provides us with accurate estimates which are extremely important in guiding management decisions. Grid trapping is an excellent means of collecting mark-recapture data while simultaneously radio-collaring, vaccinating, and collecting biological samples from foxes (Rubin et al. 2007).

Assessing the effects of climate change on endangered species is of paramount concern and importance to island managers. It is critical that baseline data on island fox activity patterns and space-use are collected now, when we are just beginning to experience the effects of climate change. We recommend in future years we collect data on island fox movements using GPS collars. These GPS data can be interfaced with weather stations and climate change models to predict alternations in space-use with changes in vegetation structure, precipitation, and temperature. These models will assist managers in anticipating the effects of climate change on island fox carrying capacity and distribution. As distribution is limited to the island, the species' range cannot shift with changes in

climate (as has been recorded in other species). Thus, land managers may be required to increase management of the island fox during those extreme weather events that might catastrophically limit critical resources. GPS collars would provide analysts with the data necessary to anticipate extreme reactions to climate change so that they may suggest options for mitigation.

We must also continue to increase the resiliency of the ecosystems of Santa Cruz Island by restoring the native plants and removing habitat-modifying weeds. TNC is committed to improving the habitat for island foxes by managing a strong and innovative weed removal program. We have used funding received from the Wildlife Conservation Board, the State Coastal Conservancy, the National Fish and Wildlife Foundation, and private donors to eradicate 18 weed species from Santa Cruz Island and restrict the distribution of four other species. We are committed to restoring native island vegetation, which will strengthen our island ecosystems against the uncertainties of climate change.

TNC has initiated a research collaborative with Colorado State University (CSU) to study the interactions between the carnivores on Santa Cruz Island, the island fox and island spotted skunk. Conventional wisdom indicates that these two species interact competitively, which result in population fluctuations of unknown magnitude (Laughrin 1973). CSU will be testing hypotheses on resource competition and the resulting effects on population density of carnivores on Santa Cruz Island. Their research will enable us to closely monitor the dynamics of intra-specific competitors, the island fox and skunk, throughout the island fox recovery period.

We suggest that TNC, DFG, and FWS implement the following recommendations to achieve successful island fox recovery and threat management:

- Continue our comprehensive management program of interagency collaboration, island-wide trapping, radio monitoring, golden eagle threat response, vaccination, and biological sample collection. This program allows TNC to adaptively manage island fox recovery, quickly respond to emerging threats and reduces the likelihood of a second extinction crisis on Santa Cruz Island.
- Purchase and deploy GPS collars to track fox movements and resource use.
- Analyze GPS data in conjunction with climate change models to re-calibrate the island fox PVA, assess the impact of climate change on island fox recovery, and dictate management actions for the next 10-50 years.
- Increase the resiliency of island ecosystems and improve habitat for the island fox by searching out and removing habitat-modifying weeds that are unintentionally introduced to Santa Cruz Island.
- Strengthen our research collaborative with Colorado State University by continuing to support graduate students interested in conducting management research on island foxes and island spotted skunks.

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Our partners at the National Park Service remain crucial collaborators in the island fox recovery effort, as in every other conservation project on Santa Cruz Island. Much thanks to Kate Faulkner, Tim Coonan, Helen Fitting, Angela Guglielmino, and Jen Savage for your very timely assistance, advice, and support throughout the last two years.

I'd like to thank our research collaborators and all the members of the Island Fox Recovery Team. Specifically, I'd like to call out contributions by Cheri Asa, Deanna Clifford, Brian Cypher, Patty Gaffney, Karl Hill, Colleen Lynch, Kathy Ralls, Winston Vickers, and Leslie Woods. I'd like thank to my agency partners Nancy Frost at the Department of Fish and Game, and Robert McMorran and Chris Kofron at the Fish and Wildlife Service. Many thanks to Tim Coonan for continuing to host the Island Fox Meetings and for providing an excellent forum wherein to share management and research priorities and progress.

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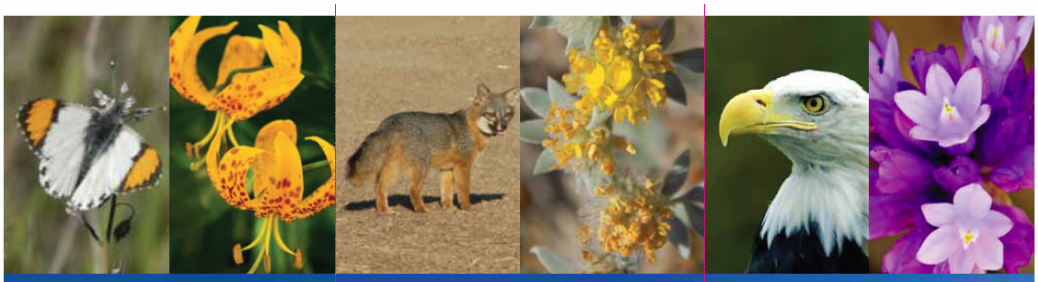
APPENDIX 1: Educational Materials



An oasis of biodiversity,

Santa Cruz Island sustains a remarkably diverse community of plants and animals, 12 of them found nowhere else on Earth. The Nature Conservancy and National Park Service have been actively restoring the Island's unique flora and fauna and reversing the legacy of 150 years of habitat degradation.

The Nature Conservancy
Protecting nature. Preserving life.™

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www.nature.org

SANTA CRUZ ISLAND'S

Return to Resilience

1800 1900 2000 2010 2020

CHUMASH ERA

Native foxes, plants and bald eagles co-exist and thrive on *Limuw*, later to be known as Santa Cruz Island.

MID-1800's

European settlers import domestic livestock and other non-native species to the island.

Introduced feral pigs and sheep destroy native vegetation, cause widespread erosion and facilitate spread of invasive weeds.

1950's

Bald Eagles disappear due to DDT contamination of ocean-based food.

Absence of this territorial bird paves the way for Golden Eagles to colonize the Island.

1990's

Golden Eagles, lured by an abundance of feral pigs, colonize the island and prey upon native island foxes.

Island fox population plunges from 1500 to fewer than 100.

1999

Program to relocate Golden Eagles back to the mainland begins.

2001

Feral sheep removed from Santa Cruz Island.

2002

Island Fox captive breeding program initiated. Bald Eagle re-establishment program begins.

2004

Island Fox listed as endangered species

2006

Bald Eagles on Santa Cruz Island hatch the first chick born on the northern Channel Islands in over 50 years.
Last nesting pair of Golden Eagles captured and relocated.

2007

Feral pig eradication program completed.

2010

Santa Cruz Island Fox population on a rapid recovery with more than 1000 foxes in the wild.

Multiple pairs of Bald Eagles nesting island-wide.

With non-native herbivores now removed, native plant species rebound.

Non-native invasive plant removal from Santa Cruz Island continues.

Vaccination program for the Island Scrub-Jay against West Nile virus implemented. Vigilant disease monitoring continues.

2020 (GOALS)

Island Fox delisted; no longer endangered.

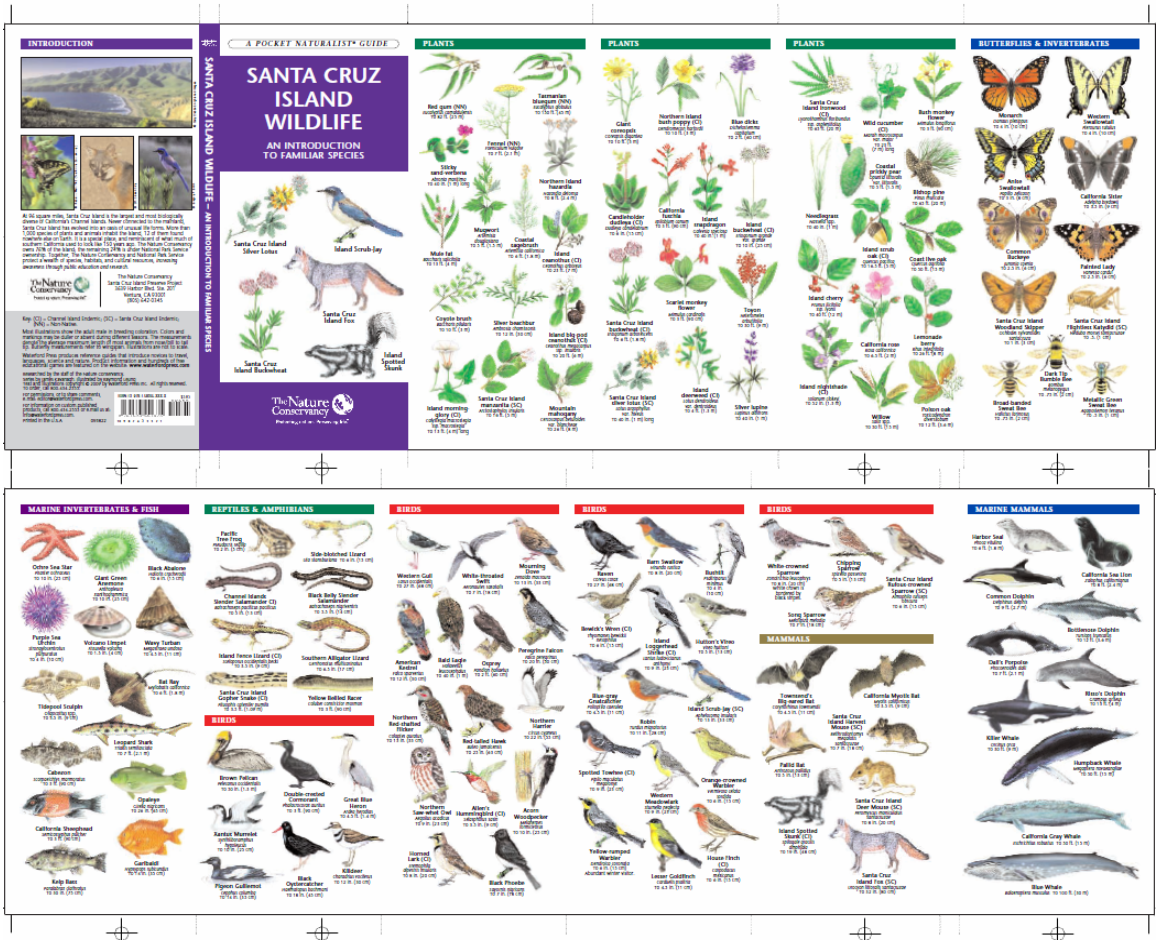
Bald Eagles re-established.

Native habitats flourishing with greater resilience to climate change impacts.

Invasive and destructive Argentine Ants controlled.

Biosecurity measures in place to reduce threat of invasive species introductions.

All-Taxa Biological Inventory of Island's unique ecological diversity.



Help Protect the Santa Cruz Island Fox

Animals from the mainland, even those that do not appear sick, can be carriers for mainland viruses. Viruses are transferred via feces, urine, or respiratory secretions.

Please help us protect island species by not bringing your pets ashore. Before leaving the mainland, check your boat carefully for wild stowaways that may swim ashore from anchored boats.

Conservation in Action!

In 1999, canine distemper virus was introduced to Santa Catalina Island, nearly causing the Catalina fox to go extinct. At the same time, golden eagles were heavily predating on foxes in the northern Channel Islands and reduced their numbers to a few dozen animals. In response, the island fox was placed on the endangered species list in 2004.

The Island Fox Recovery Group was formed to protect the foxes on all of the Channel Islands. After more than a decade of collaboration between The Nature Conservancy, National Park Service, Department of Fish and Game, and Fish and Wildlife Service, the island fox is on it's way to a successful recovery!

Please do not bring animals to the island, pack out all waste, and do not light campfires.

Island species are vulnerable to extinction because they did not evolve with mainland predators and diseases.

It's up to all of us visiting Santa Cruz Island to safeguard these unique species.

The Nature Conservancy