U.S. Fish & Wildlife Service

# Draft Recovery Plan for Four Subspecies of Island Fox

*(Urocyon littoralis)*

*Island fox.* Daniel Richards, used with permission.

# Draft Recovery Plan for Four Subspecies of Island Fox (*Urocyon littoralis*)

## (May 2012)

**Region 8**
**U.S. Fish and Wildlife Service**
**Sacramento, California**

Approved: ______________________________________________

Regional Director, Pacific Southwest Region, Region 8
U.S. Fish and Wildlife Service

Date: ____________________

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An electronic copy of this draft recovery plan will be made available at http://www.pacific.fws.gov/ecoservices/endangered/recovery/plans.html and http://endangered.fws.gov/recovery/index.html#plans

# ACKNOWLEDGEMENTS

There were many contributors to the development of this recovery plan. We would like to acknowledge the staff of the Ventura Fish and Wildlife Office, the Island Fox Recovery Coordination Group, the technical experts to the recovery team, and the researchers and field biologists for their contributions to this draft recovery plan. We appreciate the long-term commitment of the recovery team and their assistance in preparing this recovery plan over the period of development. Affiliations of the following individuals can be found in Appendix 1 of this document.

**Primary Authors**

This draft recovery plan was developed by the Island Fox Recovery Coordination Group: Brian Cypher, Carlos de la Rosa, David Graber, Devra Kleiman, Eric Morrissette, Peter Schuyler, Rebecca Shaw, Dale Steele, and Rosie Woodroffe. Peter Schuyler served as the Chair of the Recovery Team, and Eric Morrissette served as the Recovery Team Coordinator.

**Additional Contributors**

The following people provided valuable assistance in the development of this recovery plan:

Vickie Bakker, Paul Collins, Tim Coonan, Dan Doak, Julie King, Colleen Lynch, Linda Munson, Kathy Ralls, Esther Rubin, Winston Vickers, Kirk Waln, and Rachel Wolstenholme.

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We further recognize the Friends of the Island Fox, Inc. for their efforts to promote island fox conservation and recovery through public outreach and education.

# DEDICATION

This recovery plan is dedicated to the memory of Devra Kleiman and Linda Munson, who passed away in 2010. They were both instrumental in developing this plan and in constructing effective recovery actions for island foxes.

Devra served on the U.S. Fish and Wildlife Service's Island Fox Recovery Coordination Group, and as such was an author of this document. She was truly a giant in conservation biology and generously lent her considerable talents to island fox recovery. She was a passionate advocate of implementing recovery actions in a scientific manner, and of appropriate environmental education, and she successfully integrated the mainland zoo community into the island fox conservation effort. Her forthright, direct style of communication enlivened many recovery team meetings.

Linda Munson was one of the world's leading carnivore pathologists, and led studies of island fox disease and pathology since 1999. She conducted hundreds of island fox necropsies, and it is not hyperbole to say that all of our current insight into island fox health issues is due to her tireless work. Linda led the Island Fox Health Group since 1999, and under her guidance they were always the most disciplined, effective and productive of the island fox recovery team working groups. Among the issues she discovered or brought to the forefront were the unique, island-specific parasite fauna of island foxes, the nature of the canine distemper strain on Santa Catalina Island and the endemic distemper-like virus found naturally in island fox populations, chronic amyloidosis, ear tumors on Santa Catalina, and neonatal deaths from maternal neglect.

# EXECUTIVE SUMMARY

In 2004, the U.S. Fish and Wildlife Service (FWS) listed four of the six subspecies of island fox endemic to the California Channel Islands as endangered under the Endangered Species Act of 1973, as amended (Act) following catastrophic population declines (69 FR 10335). The San Miguel Island fox (*Urocyon littoralis littoralis*) went from an estimated 450 individuals to 15; the Santa Rosa Island fox (*U. l. santarosae*) declined from over 1,750 individuals to 14; the number of Santa Cruz Island foxes (*U. l. santacruzae*) went from approximately 1,450 individuals to approximately 55; and the Santa Catalina Island fox (*U. l. catalinae*) declined from over 1,300 to 103. The San Clemente Island fox (*U. l. clementae*) and the San Nicolas Island fox (*U. l. dickeyi*) were not federally listed, as their population numbers had not experienced similar declines. However, both non-federally listed subspecies could experience the same type of population decline as those subspecies that are federally listed. Additionally, all six subspecies are listed as threatened by the State of California. Therefore, the San Clemente and San Nicolas Island fox subspecies are included for discussion in this plan where appropriate.

The Channel Islands inhabited by island foxes are owned by four major landowners: the National Park Service (NPS), the U.S. Navy (Navy), The Nature Conservancy (TNC), and the Santa Catalina Island Conservancy (CIC). Although San Miguel Island is owned by the Navy, the NPS manages the island. The NPS, TNC, and CIC manage the islands where the listed subspecies occur. The FWS guides the recovery planning process for the four listed island fox subspecies under the Act. In addition, the State of California has regulatory authority over the island fox on non-Federal lands because the species is listed as threatened under the California Endangered Species Act.

The two primary known threats resulting in the listing of the four subspecies of island fox as federally endangered were: 1) predation by golden eagles (*Aquila chrysaetos*) (San Miguel Island fox, Santa Rosa Island fox, and Santa Cruz Island fox) and 2) the transmission of canine distemper virus (Santa Catalina Island fox). Additionally, because the size of each island fox population is small, they are highly vulnerable to **stochastic events** and the effects of low genetic diversity. Other threats that have either contributed to the decline of island foxes or continue to affect the island fox subspecies and/or their habitat include mortality from vehicle strikes; other diseases and parasites; competition

with feral cats, deer, and pigs; habitat degradation from grazing; fire; and exposure to toxins.

The current knowledge regarding the evolution, ecology, behavior, and population biology of island foxes has been amassed by numerous researchers from around the country. Collaboration with researchers has been, and will continue to be, critically important in understanding island fox natural history and recovery challenges.

Recovery of each subspecies of island fox will be achieved by removing, or substantially reducing, known threats and increasing populations to viable levels for long-term survival of each subspecies. The strategy of this recovery plan is to continue the current recovery efforts and to improve and expand recovery actions as necessary. Recent and ongoing island fox recovery efforts include: removing golden eagles from the northern Channel Islands; reducing the threat of disease; breeding island foxes in captivity and reintroducing them to the wild; monitoring wild island fox populations; removal of non-native species (e.g., golden eagle prey); and reintroducing bald eagles (*Haliaeetus leucocephalus*) with the goal of deterring golden eagles from establishing territories on the Channel Islands. Additionally, ongoing activities that contribute to a long-term conservation strategy include: conducting research on behavioral ecology and reproductive biology; increasing island fox education and outreach activities to reduce anthropogenic impacts; restoring island habitat; and assessing the **demographic** impact of other threats such as mortality from vehicles, competition with feral cats, and emerging disease issues (e.g., ear cancer).

Since 1999, island fox recovery efforts by the land management agencies (NPS, TNC, and CIC) have included efforts to reduce the two major threats to island foxes that caused the precipitous declines. Mortality due to golden eagle predation on the three island fox subspecies from the northern Channel Islands (San Miguel, Santa Rosa, and Santa Cruz Islands) has been reduced, while the threat posed by disease to Santa Catalina Island foxes has been ameliorated. All land management efforts have included bringing wild island foxes into captivity to serve as a temporary sanctuary from threats, increasing populations of each subspecies through captive breeding, and releasing captive individuals back into the wild. For a period of time, the entire San Miguel Island and Santa Rosa Island fox populations were held in captivity.

Recovery efforts to date have increased the numbers of foxes on all islands and reduced the risk of extinction. Wild populations of island foxes have been re-established on San Miguel and Santa Rosa Islands. Predation has been a negligible mortality factor on San Miguel Island and Santa Cruz Island, where annual survival of island foxes has remained greater than 90 percent since 2004 for San Miguel Island and 2008 for Santa Cruz Island. Annual survival has been greater than 80 percent on Santa Rosa Island from 2007-2009, though eagle predation occurred again in 2010.

Following disease mitigation efforts, the Santa Catalina Island fox population is increasing and, if this trend continues, may meet recovery criteria in the near future. The threat posed by ear tumors is of continued concern for the Santa Catalina Island fox. Potential threats to the Santa Catalina Island foxes include competition with feral cats, mortality from vehicle strikes, and the introduction of infectious disease.

**Recovery Goal:** The goal of this recovery plan is to recover the San Miguel Island fox, the Santa Rosa Island fox, the Santa Cruz Island fox, and the Santa Catalina Island fox so they can be delisted (removed from listing under the Act) when existing threats to each respective subspecies have been ameliorated, thereby stabilizing and augmenting their populations. Each listed subspecies may be considered for downlisting or delisting independently of the other subspecies.

**Recovery Objectives:** Recovery objectives identify mechanisms for measuring progress toward and achieving the recovery goal for each subspecies. Achieving the recovery goal requires: 1) increasing the population size to levels and demographic rates that are self-sustaining, and 2) reducing or eliminating the current threats to the survival of each subspecies.

**Recovery Objective 1:**

Each subspecies of island fox exhibit demographic characteristics consistent with long-term viability.

**Recovery Objective 2:**

Conservation measures and practices are in place, such that land managers are able to respond in a timely fashion to potential and ongoing predation by golden eagles, to potential or incipient disease outbreaks, and to other identified threats.

In order for any one of the four listed subspecies of island fox to be considered for downlisting from endangered to threatened status, recovery objective 1 should be met.

In order for any one of the four listed subspecies of island fox to be considered for delisting from endangered or threatened to delisted status, recovery objective 1 and recovery objective 2 should be met.

**Recovery Criteria**

Recovery criteria are measurable standards for determining that a species has achieved its recovery objectives and may be considered for downlisting or delisting. The recovery criteria presented in this draft recovery plan represent our best assessment of the conditions that would most likely result in a determination that downlisting and/or delisting of the San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, or Santa Catalina Island fox is warranted.

<u>Population Risk-based Recovery Criteria</u>

Recovery criterion 1 was developed to address recovery objective 1.

Recovery Criterion 1:

An island fox subspecies has no more than 5 percent risk of quasi-extinction over a 50 year period. This risk level is based upon the following:

- Quasi-extinction is defined as a population size of ≤30 individuals.
- The risk of extinction is calculated based on the combined lower 80 percent confidence interval for a 3 year running average of population size estimates, and the upper 80 percent confidence interval for a 3 year running average of mortality rate estimates.
- This risk level is sustained for at least 5 years, during which time the population trend is not declining.

This risk-based recovery criterion is based on models developed separately for each listed subspecies.

Threat-based Recovery Criteria

To meet recovery objective 2, recovery criteria 2.1 and 2.2 are achieved.

Recovery Criterion 2.1 – Golden Eagle Predation:

To reduce the threat of extinction to the San Miguel Island fox, the Santa Rosa Island fox, and the Santa Cruz Island fox from golden eagle predation:

1. A golden eagle management strategy is developed and approved by the land manager(s) in collaboration with the FWS and including review by the appropriate Integrated Island Fox Recovery Team (IRT) Technical Expertise Group (TEG) or the equivalent. This strategy must include:

   - Response tactics to capture golden eagles responsible for island fox predation;
   - Tactics to minimize the establishment of successful nesting golden eagles;
   - An established island fox monitoring program for each subspecies that is able to detect an annual island fox predation rate caused by golden eagles of 2.5 percent or greater, averaged over 3 years (Bakker and Doak 2009); and
   - An established mortality rate or population size threshold for each subspecies of island fox that, if reached due to golden eagle predation, would require the land manager(s) to bring island foxes into captivity for safety.

2. The golden eagle prey base of deer and elk is removed from Santa Rosa Island. At present, golden eagles are not known to prey upon Santa Catalina Island foxes. If mortality as a result of golden eagle predation becomes a threat to the Santa Catalina Island fox, the golden eagle management strategy will be implemented.

Recovery Criterion 2.2 – Disease:

To reduce the threat of extinction to the San Miguel Island fox, the Santa Rosa Island fox, the Santa Cruz Island fox, and the Santa Catalina Island fox from disease:

1. A disease management strategy is developed and approved by the land manager(s) in collaboration with the FWS and including review by the appropriate IRT TEG or the equivalent. This strategy must include:

    - Identification of a portion of each subspecies that will be vaccinated against diseases posing the greatest risk and for which vaccines are safe and effective. Vaccinations to be provided and numbers vaccinated will be developed in consultation with appropriate subject-matter experts;
    - Identification of actual and potential pathogens of island foxes, and the means by which these can be prevented from decimating fox populations;
    - Measures to prevent diseases in island foxes;
    - A monitoring program that provides for timely detection of a disease outbreak, and an associated emergency response strategy as recommended by the appropriate subject-matter experts; and
    - A process for updating the disease management strategy as new information arises.

**Recovery Actions**

The actions identified below are those that, in our opinion, are necessary to bring about the recovery of island foxes. These actions are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions.

1. Reduce mortality and maintain productivity for each subspecies of island fox to ensure populations persist at sustainable levels.

2. Manage captive populations of island foxes for recovery.

3. Establish island fox monitoring strategies.

**Estimated Total Cost of Recovery**

$7,615,500 + to be determined

Long-term Conservation Strategy

The long-term conservation strategy included herein identifies actions that would further the conservation of the island fox. Long-term conservation may be benefitted by conducting research on behavioral ecology and reproductive biology; increasing island fox education and outreach activities to reduce anthropogenic impacts; restoring island habitat; and assessing the **demographic** impact of other threats such as mortality from vehicles, competition with feral cats, and emerging disease issues (e.g., ear cancer). At this time, these activities are not essential for preventing extinction and are not required for downlisting or delisting a particular island fox subspecies; however, these activities could substantially enhance the long-term conservation of the species and may also increase our scientific understanding of the island fox. In the event that an island fox subspecies is recovered and delisted, completion of these actions may further reduce the potential for any of the subspecies to be relisted in the future.

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NOTE: Words and terms found with bold font throughout the Plan are defined in Appendix 9

# I. Background

## A. INTRODUCTION

The island fox (*Urocyon littoralis*), a diminutive relative of the gray fox (*U. cinereoargenteus*), is endemic to the California Channel Islands. Island foxes inhabit six of the eight Channel Islands (San Miguel Island, Santa Rosa Island, Santa Cruz Island, Santa Catalina Island, San Nicolas Island, and San Clemente Island) and are recognized as a distinct subspecies on each of the six islands (Figure 1). Both morphologic and genetic distinctions support the classification of separate subspecies for each island (Collins 1993; Gilbert et al. 1990; Goldstein et al. 1999; Wayne et al. 1991a).

### Legal Status

Four of the six island fox subspecies experienced catastrophic declines in the late 1990s, due to golden eagle predation on the northern Channel Islands (San Miguel Island, Santa Rosa Island, and Santa Cruz Island) and due to a suspected canine distemper virus (CDV) outbreak (Table 1) on Santa Catalina Island. In June 2001, the Center for Biological Diversity petitioned the U.S. Fish and Wildlife Service (FWS) to list the four subspecies in catastrophic decline as endangered as defined by the Endangered Species Act of 1973, as amended (Act). In 2004, the Service listed the San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, and Santa Catalina Island fox as endangered (U.S. Fish and Wildlife Service 2004) pursuant to the Act. The remaining two subspecies, the San Nicolas Island fox (*U. l. dickeyi*) and San Clemente Island fox (*U. l. clementae*), did not experience the same type of population declines and thus, were not federally listed.

The California Fish and Game Commission listed the island fox as a rare species in 1971. All animals that had been determined to be rare on or before January 1, 1985 were designated as "threatened species" at that time. The IUCN (World Conservation Union) listed the entire species as Critically Endangered in 2001 (Sillero-Zubiri and Macdonald 2004).

The San Clemente Island fox (*U. l. clementae*) and the San Nicolas Island fox (*U. l. dickeyi*) are not federally listed, as their population numbers did not experience similar declines. However, all six subspecies are listed as threatened by the State of California. Therefore, the San Clemente Island fox (*U. l. clementae*) and the

San Nicolas Island fox (*U. l. dickeyi*) subspecies are included for discussion in this plan.

Following the Federal listing of the island fox in 2004, the FWS considered designating critical habitat for the four listed subspecies. However, in its final determination concerning critical habitat for the island fox (U.S. Fish and Wildlife Service 2005), the FWS concluded that no habitat met the definition of critical habitat in the Act and therefore, did not designate any critical habitat for any of the four subspecies. Critical habitat is defined in section 3(5)(A) of the Act in part as: the specific areas within the geographical area occupied by a species, at the time it is listed in accordance with the Act, on which are found those physical or biological features essential to the conservation of the species and that may require special management considerations or protection. The FWS did not designate any critical habitat for the island fox because: 1) the island fox is a habitat generalist and an opportunistic omnivore; 2) the primary reasons for the listing of the fox were predation and disease; and 3) prior to predation by golden eagles and the outbreak of disease, habitat did not appear to be a limiting factor despite human-induced habitat changes that have occurred. The FWS concluded that there are no specific areas where physical or biological features are essential to the conservation of the species and that may require special management considerations or protection; therefore, designating critical habitat would not be beneficial.

**Table 1. Estimated number of wild adult and juvenile island foxes for each subspecies.**

| Island/ Subspecies | 1994 Estimate[1] | 1999/2000 Estimate[2] | 2009/2010 Estimate[3] |
|---|---|---|---|
| San Miguel* | 450 | 15 | 516 |
| Santa Rosa* | 1,780 | 14 | 292 |
| Santa Cruz* | 1,465 | 55 | >1200 |
| Santa Catalina* | 1,342 | 103 | 947 |
| San Clemente | 1,003 | 535 | 714 |
| San Nicolas | 520 | 452 | 515 |

* federally listed endangered subspecies.
[1]source: Roemer et al. (1994).
[2]sources: Coonan et al. (2005b); Timm et al. (2002); Roemer et al. (2002)
[3]source: Boser (2011); Coonan (2010); Coonan (2011), D. Garcelon, Institute for Wildlife Studies, pers. comm. 2011

### Affected Agencies, Landowners, and Partners

Islands inhabited by island foxes are owned by four major landowners: the National Park Service (NPS), the U.S. Navy (Navy), The Nature Conservancy (TNC), and the Santa Catalina Island Conservancy (CIC), all of whom have management authority for wildlife on their lands (Figure 1, Table 2). The NPS, TNC, and CIC manage the islands where the listed subspecies occur. The FWS guides the recovery planning process for the four listed island fox subspecies under the Act. Additionally, the State of California has regulatory authority over the island fox on non-Federal lands.

The bulk of the current knowledge regarding the evolution, ecology, behavior, and population biology of island foxes has been amassed by researchers from California institutions, including the University of California (Los Angeles, Davis, Santa Barbara, and Santa Cruz), California State University (Los Angeles),

**Figure 1. Channel Islands Land Ownership**

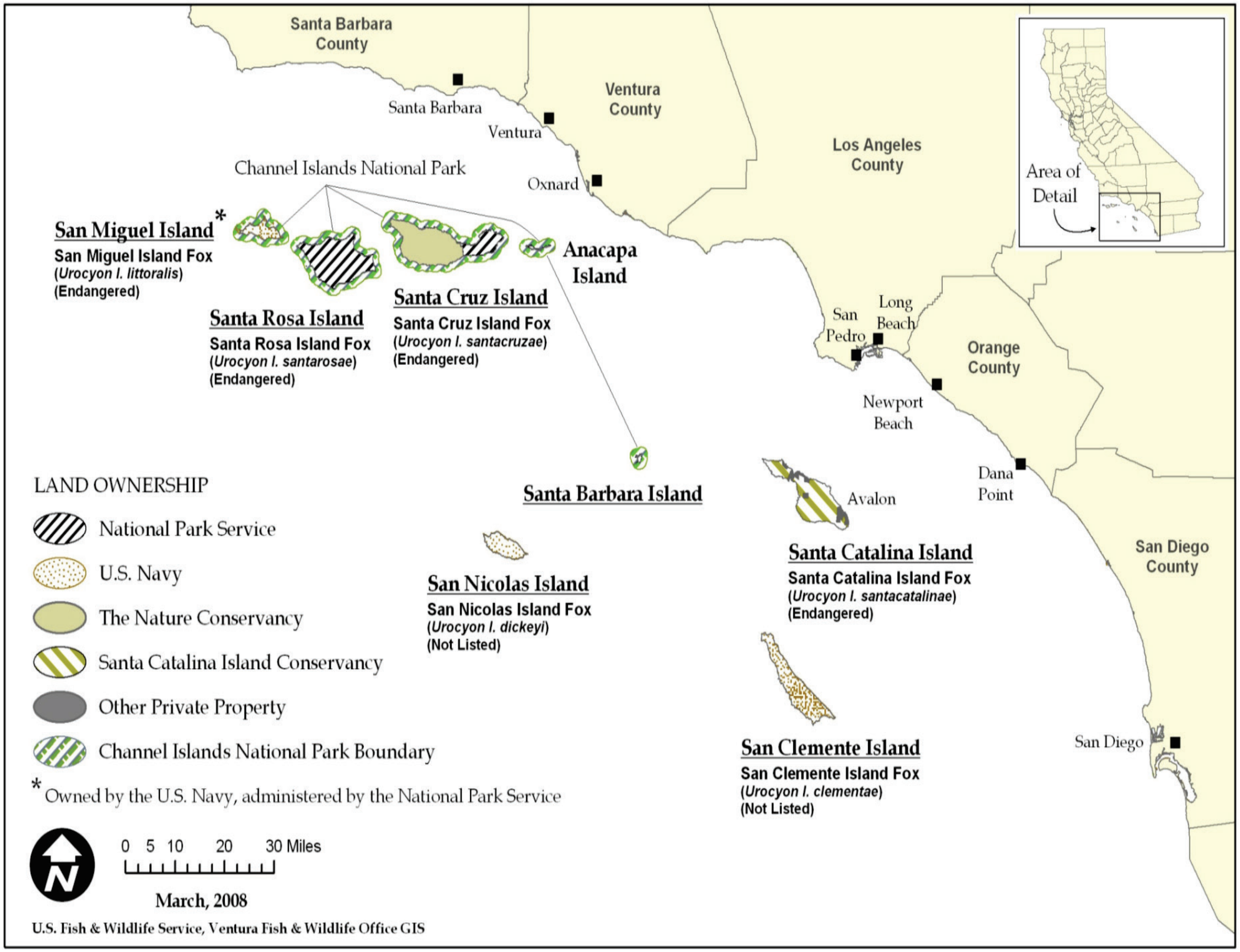

**Table 2. Ownership and management of the California Channel Islands inhabited by island fox**

| Island | Island size ($km^2$) | Island Management/Ownership[1] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Federal Agency | | The Nature Conservancy | Santa Catalina Island Conservancy | Other Private Property | |
| | | National Park Service | U.S. Navy | | | Santa Catalina Island Company[5] | Other Private Landowners[6] |
| San Miguel[2,3] | 39 | 100% (manager) | 100% (owner) | | | | |
| Santa Rosa[2,3] | 216 | 100% | | | | | |
| Santa Cruz[2,3,4] | 243 | 24% | | 76% | | | |
| Santa Catalina[3] | 194 | | | | 88% | 11% | 1% |
| San Clemente | 149 | | 100% | | | | |
| San Nicolas | 58 | | 100% | | | | |

[1]Both land owner and manager except as noted.
[2]Entire island within Channel Islands National Park boundary.
[3]Federally-listed endangered subspecies of island fox present.
[4]The Park and TNC cooperate fully on resources management and research issues via a cooperative agreement.
[5]The majority of this land is developed.
[6]These include home owners in the town of Avalon, the Wrigley Marine Science Institute run by University of Southern California, and Southern California Edison – the utility company that provides power, water, and gas for Catalina Island.

the Santa Barbara Museum of Natural History, and the non-profit Institute for Wildlife Studies (IWS).

In addition, researchers from a number of other U.S. institutions and organizations, including the Association of Zoos and Aquariums (AZA), Conservation Breeding Specialist Group (SSC/IUCN), the Honolulu Zoo, the Lincoln Park Zoo, New Mexico State University, the Santa Barbara Zoo, the Saint Louis Zoo, and the U.S. Geological Survey – Biological Resource Discipline (USGS-BRD) have contributed to the understanding of island fox natural history and recovery challenges. Collaboration with researchers has been, and will continue to be, critically important for island fox recovery efforts.

**Integration of Conservation and Recovery Efforts**

By 1999, island fox populations on the northern Channel Islands were considered to be in need of immediate conservation action (Coonan et al. 1998; Roemer 1999). The NPS convened a multi-disciplinary group of experts in 1999 (Island Fox Conservation Working Group) to evaluate available island fox status information and develop strategies to recover the island fox populations to viable levels. This was a loose affiliation of public agency representatives, landowners, conservancies, zoological institutions, non-profits, and academics concerned about conservation efforts for the island fox.

This group met annually from 1999 through 2004 and broadened its focus to include concerns about all six island fox subspecies. The working group served as a forum for information exchange and evaluation of recovery efforts. To address most issues, the group further divided into subject matter groups, such as management of wild populations, management of captive populations, island fox husbandry, veterinary issues, policy issues, and educational outreach needs. The group reported annually on the status of island foxes on all islands and listed findings regarding threats to the species and appropriate mitigation actions (Coonan and Rutz 2001, 2002, 2003; Coonan et al. 2004, 2005a).

In 2004, after four of the six subspecies were federally listed, the island fox Integrated Recovery Team (IRT; see Appendix 1) was established and incorporated the expertise of all 70+ individuals from the former working group. At the same time, the island fox Recovery Coordination Group (RCG; see

Appendix 1) was established with representatives from each of the land management agencies as well as additional canid experts. The FWS' goal for the RCG was both to draft the recovery plan using the knowledge and expertise of the IRT and to advise the FWS on immediate conservation needs. Tasks regarding management and recovery of island foxes were developed by the RCG and submitted to a task force for analysis; each task was formally referred to as a Technical Analysis Request. Each task force group was comprised of individuals from the larger IRT. In addition to incorporating the information into this draft recovery plan, the RCG forwarded the resulting analyses to the FWS, with recommendations for recovery actions needed immediately. The FWS then transmitted the analyses and recommendations to the land management agencies so that ongoing recovery efforts could take advantage of the best available information prior to the formal completion of an approved recovery plan. Since 2004, the land management agencies have received recommendations regarding releases from captivity and post-release monitoring, management and husbandry for captive populations, management of golden eagles, and establishment of a mainland captive population. The RCG also organized two population viability analysis meetings for the four federally listed subspecies, a monitoring workshop, and coordinated the annual island fox meetings in 2005 and 2006.

Since 1999, island fox recovery actions by the land management agencies have included efforts to reduce the two major threats that caused the precipitous population declines of the four island fox subspecies. Mortality due to golden eagle predation on the three island fox subspecies from the northern Channel Islands has been reduced, while the threat posed by CDV to the Santa Catalina Island foxes has been ameliorated. All land management efforts have been accomplished by bringing island foxes into captivity to serve as a temporary sanctuary from threats and to increase populations of each subspecies through captive breeding.

## B. BIOLOGICAL INFORMATION

### 1. Description and Taxonomy

A diminutive relative of the mainland gray fox, the island fox weighs approximately 1.8 to 3.0 kilograms (kg) (3 to 6 pounds (lb)) and stands approximately 30 centimeters (cm) (12 inches (in)) tall. The island fox is distinguished from the gray fox by its darker **pelage** and its smaller size (Collins 1982); most linear measurements of island foxes are 25 percent smaller than those of the gray fox. The dorsal coloration is grayish-white and black, and the base of the ears and sides of the neck and limbs are cinnamon-rufous in color (Moore and Collins 1995). The underbelly is a dull white, and the tail is conspicuously short. Island foxes display sexual size dimorphism, with males being larger and heavier than females (Collins 1982, 1993).

The island fox was first described as *Vulpes littoralis* by Baird in 1857 from the type locality on San Miguel Island, Santa Barbara County, California (Baird 1857). Merriam (1888, in Hall and Kelson 1959) reclassified the island fox into the genus *Urocyon* and later described island foxes from Santa Catalina, San Clemente, and Santa Cruz Islands as three separate species (U. *catalinae*, *U. clementae*, and *U. littoralis santacruzae*) (Merriam 1903). Grinnell et al. (1937) revised Merriam's classification, placing foxes from all islands under the species *U. littoralis* and assigning each island population a subspecific designation (*U. l. catalinae* on Santa Catalina Island, *U. l. clementae* on San Clemente Island, *U. l. dickeyi* on San Nicolas Island, *U. l. littoralis* on San Miguel Island, *U. l. santacruzae* on Santa Cruz Island, and *U. l. santarosae* on Santa Rosa Island). Recent morphological and genetic studies support this division of the *U. littoralis* complex into six subspecies, each restricted in range to a single island (Collins 1991a, 1993; Gilbert et al. 1990; Goldstein et al. 1999; Wayne et al. 1991a, 1991b).

## 2. Distribution, Evolution, and Genetics

Island foxes inhabit the six largest California Channel islands off the coast of southern California (San Miguel Island, Santa Rosa Island, Santa Cruz Island, San Nicolas Island, Santa Catalina Island, and San Clemente Island). Genetic evidence suggests that all island foxes are descended from one colonization event (George and Wayne 1991), possibly from chance, over-water dispersal by rafting on floating debris (Moore and Collins 1995). Fossil evidence indicates that island foxes have been on the northern Channel Islands (Santa Cruz, Santa Rosa, and San Miguel Islands) for at least 16,000 years (Orr 1968). Island foxes may have existed on the northern Channel Islands during a period when Santa Cruz, Santa Rosa, and San Miguel Islands were one land mass referred to as "Santarosae," last known to have been united 18,000 years before present (Johnson 1978, 1983). Island foxes may have reached the southern Channel Islands (San Nicolas, San Clemente, and Santa Catalina Islands) much more recently (2,200 to 3,800 years ago), and were most likely introduced to these islands by Native Americans as pets or semi-domesticates (Collins 1991a, b). Island fox remains recently recovered from San Nicolas Island extend this time period to approximately 5,200 years before present (Vellanoweth 1998).

Morphologically, the species exhibits inter-island variability in size, nasal shape and projection, and the number of tail vertebrae (Collins 1982). Genetic evidence supports the separation of the species into six distinct subspecies, and confirms the pattern of dispersal suggested by archeology and geology. A study of genetic variability in **DNA restriction fragments** in island foxes (Gilbert et al. 1990) revealed that inter-island variability was greater than intra-island variability. **Phylogeny** based upon restriction fragment variability supports the geological evidence for the sequence of isolation of each island, and each population, as rising sea levels separated *Santarosae* into the northern Channel Islands. Santa Cruz Island separated from the other northern islands first, about 11,500 years ago, followed by the separation of San Miguel Island and Santa Rosa Island about 9,500 years ago. Together with the fossil record, restriction fragment evidence indicates that San Clemente Island was the first southern Channel Island colonized, probably by immigrants from San Miguel Island. Dispersal then occurred from San Clemente Island to San Nicolas and Santa Catalina Islands.

Island forms generally have less genetic variability than their mainland counterparts. Mainland gray foxes were found to be more variable in morphology, **allozymes**, mitochondrial DNA, and hypervariable nuclear DNA than island foxes (Goldstein et al. 1999; Wayne et al. 1991a). The island fox populations with the fewest numbers of individuals, San Miguel Island and San Nicolas Island, showed the least genetic variability, and the San Nicolas Island population was actually monomorphic (showing no variation) in allozyme, hypervariable minisatellite and microsatellite DNA, and mitochondrial DNA, which is highly unusual among mammals. This lack of variability could be attributed either to extensive inbreeding or to **bottlenecking** resulting from low population densities (George and Wayne 1991). On San Miguel and San Nicolas Islands, the species has apparently existed for thousands of years at low **effective**

**population sizes** (150 to 1000), with low genetic variability (Wayne et al. 1991a, 1991b). The Santa Rosa Island and San Miguel Island populations have been shown to be closely related.

Recently, Aguilar et al. (2004) found considerable variation at the major histocompatibility complex (MHC) in San Nicolas Island foxes, which contain genes that code for disease resistance and kin recognition. Modeling by the authors suggests that the pattern of MHC and neutral marker variation in San Nicolas Island foxes was caused by an extreme bottleneck (a decline to fewer than 10 animals) in the past 10 to 20 generations.

Recently, genetic relatedness among individuals was determined for the San Miguel Island and Santa Rosa Island captive populations (Gray et al. 2001; Gray 2002). Analysis of island fox blood samples from 1988 and from the captive population (at the time of the study) indicated that the level of variation in island foxes on the two islands had declined since 1988. During that time period, there was a reduction in the number of **alleles** at some **loci** and, at some loci, a complete loss of **polymorphism**.

### 3. Habitat Use and Food Habits

The island fox is a habitat generalist, occurring in all natural habitats on the Channel Islands, although it prefers areas of diverse topography and vegetation (von Bloeker 1967; Laughrin 1977; Moore and Collins 1995). Island foxes occur in valley and foothill grasslands, southern coastal dune, coastal bluff, coastal sage scrub, maritime cactus scrub, island chaparral, southern coastal oak woodland, southern riparian woodland, Bishop and Torrey pine forests, and coastal marsh habitat types. Crooks and Van Vuren (1996) found island foxes to prefer fennel *(Foeniculum vulgare)* and to avoid ravines and scrub oak patches on Santa Cruz Island. Island foxes may use non-native grasslands less than other habitats, even though insect prey is abundant in grasslands, because grasslands are denser and may be more difficult to forage in (Roemer and Wayne 2003). Also, low vegetation types such as grasslands may render island foxes more vulnerable to aerial predators (Roemer 1999).

Island foxes are omnivores and forage opportunistically, eating a wide variety of seasonally available plants and animals (Collins 1980; Collins and Laughrin 1979;

Crooks and Van Vuren 1995; Kovach and Dow 1981; Laughrin 1973, 1977; Moore and Collins 1995). Island foxes feed on a wide variety of insect prey, such as grasshoppers, crickets, and katydids (Crooks and Van Vuren 1995; Moore and Collins 1995) and Jerusalem crickets *(Stenopelmatus fuscus)* when seasonally available (Moore and Collins 1995).

Island foxes prey on native deer mice *(Peromyscus maniculatus)* on all islands and also likely prey upon introduced house mice *(Mus musculus)* on Santa Catalina Island and introduced rats *(Rattus rattus)* on Santa Catalina, San Miguel, and San Clemente Islands. Deer mice may be especially important prey during the breeding season, because they are large, energy-rich food items that adult foxes can bring back to their growing pups (Garcelon et al. 1999). In addition to small mammals, island foxes prey on ground-nesting birds such as horned larks *(Eremophila alpestris)* and western meadowlarks *(Sturnella neglecta)*. Less common in the diet are amphibians, reptiles, and the carrion of marine mammals (Collins and Laughrin 1979). Island foxes feed on a wide variety of native plants, including the fruits of *Arctostaphylos, Comarostaphylis, Heteromeles, Opuntia, Prunus, Rhus, Rosa, Solanum*, and *Vaccinium* (Moore and Collins 1995). San Miguel Island foxes rely more on the fruits of sea-fig, *Carpobrotus chilensis*. A comprehensive treatment of island fox diet is found in Moore and Collins (1995).

The island fox is a **docile canid**, exhibiting little fear of humans in many instances. Although primarily nocturnal, the island fox is more **diurnal** than the mainland gray fox (Collins and Laughrin 1979; Crooks and Van Vuren 1995; Fausett 1993), possibly a result of historical absence of large predators and freedom from human harassment on the islands (Laughrin 1977).

## 4. Social Organization and Reproduction

Island foxes generally have smaller territories, exist at higher densities, and have shorter dispersal distances than mainland fox species, characteristics typical of vertebrate populations on islands (Roemer 1999; Roemer et al. 2001c). Island fox home range size and configuration are dependent on landscape features, resource distribution, fox population density, habitat type, season, and sex of the animal (Fausett 1982; Laughrin 1977; Crooks and Van Vuren 1996; Thompson et al. 1998). Recorded home-range estimates range from 0.24 square kilometer ($km^2$) (0.09 square mile ($mi^2$)) in mixed habitat (Crooks and Van Vuren 1996) and 0.87

km$^2$ (0.34 mi$^2$) in grassland habitat (Roemer 1999) on Santa Cruz Island, to 0.77 km$^2$ (0.3 mi$^2$) in canyons on San Clemente Island (Thompson et al. 1998). Island fox territory size on Santa Cruz Island varied from 0.15 to 0.87 km$^2$ (0.06 to 0.34 mi$^2$) and averaged 0.55 km$^2$ (0.21 mi$^2$) during a period of moderate to high fox density (7 island foxes per km$^2$ [18 per mi$^2$]) (Roemer et al. 2001c).

Recent research on Santa Cruz Island found that island foxes, like most foxes, exist as socially monogamous pairs occupying discrete territories (Roemer et al. 2001c). Territory configuration changed after the death and replacement of paired male foxes, but not after the death and replacement of paired females or juveniles, indicating that adult males are involved in territory formation and maintenance. Despite being socially monogamous and territorial, island foxes are not necessarily genetically monogamous. On Santa Cruz Island, 4 of 16 offspring whose parents were identified by paternity analysis were a result of extra-pair fertilizations (Roemer et al. 2001c). All extra-pair fertilizations occurred between foxes from adjoining territories.

Island fox courtship activities occur from late January to early March (Moore and Collins 1995). In the island fox captive breeding facility on San Miguel Island, copulations were observed during the first 2 weeks of March 2000, and copulation for the successful pairs likely occurred between mid-February and early March (Coonan and Rutz 2001, 2002). Young are born from early to late April after a gestation period of approximately 50 to 53 days. Births occurred in NPS' island fox captive breeding facilities from April 1 to April 25 (Coonan et al. 2010).

Island foxes give birth to their young in simple dens, under shrubs, or in the sides of ravines (Laughrin 1973). Litter size ranges from one to five (Moore and Collins 1995); mean litter size for 24 dens on Santa Cruz Island was 2.17 (Laughlin 1977). The average number of foxes produced in 51 litters in captivity from 1999 to 2004 was 2.4 (Coonan et al. 2005a). Like other fox species, island foxes exhibit biparental care (care by both parents), evidenced by the capture of adult male foxes in the same traps as pups and observations of adults and known offspring foraging together (Garcelon et al. 1999; Roemer 1999). By 2 months of age, young foxes spend most of the day outside the den and will remain with their parents throughout the summer. Some pups disperse away from their natal territories by winter, although others may stay on their natal territories into their second year.

Although island foxes are physiologically capable of breeding at the end of their first year (Laughrin 1977), most breeding involves older animals. Coonan et al. (2000) found that only 16 percent of 1 to 2 year old females bred over a 5 year period on San Miguel Island, in contrast to 60 percent of older females. Roemer (1999) found yearling females to have lower fertility than older females on Santa Cruz Island. However, females reintroduced from captive facilities on San Miguel Island have produced litters at 1 year of age (T. Coonan, National Park Service, pers. comm. 2006).

Prior to the catastrophic population declines of the 1990s, adult island foxes were reported to live an average of 4 to 6 years (Moore and Collins 1995); Coonan et al. (1998) recorded eight individuals on San Miguel Island that lived 7 to 10 years in the wild.

## 5. Mortality Sources and Population Dynamics

In an effort to describe the basic biology and life history characteristics of the island fox, the following section describes current and historic sources of mortality to the island fox, as well as the population dynamics of the species. In many cases, there is an overlap between the sources of mortality described here and the current threats to the species. However, the specific threats to the species are considered more fully in the section of this document entitled, "Threats to the Species."

**(a) Golden Eagles.** Predation by golden eagles drove the island fox subspecies on San Miguel, Santa Cruz, and Santa Rosa Islands to near extinction in the late 1990s (Roemer 1999; Roemer et al. 2001a; Coonan et al. 2005c). Golden eagle predation has continued to be the primary mortality factor for foxes on the northern Channel Islands.

The extirpation of bald eagles (*Haliaeetus leucocephalus*) from the Channel Islands as a result of dichlorodiphenyltrichloroethane (DDT) may have facilitated golden eagle colonization. Bald eagles historically bred on the islands and aggression by breeding bald eagles may have discouraged foraging golden eagles from establishing residence. Bald eagles are represented in the prehistoric fossil record of the northern Channel Islands (Guthrie 1993) and bred there until 1960, when nest failures, as a result of DDT contamination, extirpated them from the northern Channel Islands (Kiff 1980). The northern Channel Islands (Anacapa, Santa Cruz, Santa Rosa, and San Miguel Islands) likely supported more than 14 pairs of bald eagles before their decline (Kiff 1980).

Bald eagles normally rely on marine resources as a food resource base, while golden eagles traditionally focus on terrestrial species. Additionally, on much of the northern Channel Islands, historic sheep grazing changed the predominant vegetation from shrub to non-native grasslands, which offered foxes much less cover from aerial predators.

Except for golden eagles, red-tailed hawks (*Buteo jamaicensis*) are the only other confirmed avian predator of island foxes (Laughrin 1980; Moore and Collins 1995). There have been unconfirmed historical reports of predation by bald eagles, but there is no current or recent evidence to suggest that foxes are a dominant prey item of bald eagles. Island fox remains have been found in bald eagle nests; however, it is not known whether the individuals were predated or scavenged (P. Collins, Santa Barbara Museum of Natural History, pers. comm. 2007).

**(b) Canine Distemper Virus.** A canine distemper virus (CDV) outbreak was the suspected cause of decline for the island fox population on Santa Catalina Island. This disease remains a potential mortality factor for island foxes and is capable of causing a catastrophic decline (Timm et al. 2000, 2002; Kohlmann et al. 2005). A recent **serological** survey recorded the presence of antibodies reactive against CDV in wild foxes on all islands except San Miguel Island (Clifford et al. 2006), suggesting that exposure to CDV has occurred in multiple island fox subspecies, with survival of many infected individuals. Exposure to most **morbilliviruses**, such as CDV, confers lifelong immunity in survivors, so animals with antibodies may have protection against CDV.

**(c) Other Factors.** Additional mortality factors for island foxes include vehicle strikes on roads, other diseases, parasites, accidents, fire, and toxin exposures. At least one case of island fox mortality due to shooting by an unknown person(s) was confirmed in 2007 on Santa Catalina Island (J. King, Santa Catalina Island Conservancy, pers. comm. 2007). Collision with motor vehicles remains a threat to island foxes on San Nicolas and San Clemente Islands (Moore and Collins 1995) and on Santa Catalina Island (Munson 2010). On Santa Catalina Island, annual averages of four foxes per year were killed by vehicles from 2002 to 2007. On San Nicolas Island, 20 to 40 foxes are killed by vehicles annually (G. Smith, U.S. Navy, pers. comm. 2007). Vehicle speed limits have been lowered and educational efforts increased in an attempt to reduce vehicle related mortality on San Nicolas Island. More than 30 foxes are killed by vehicles annually on San Clemente Island (Garcelon et al. 2008).

Island foxes have shown previous exposure to infectious agents such as canine parvovirus, canine adenovirus, canine corona virus, canine herpes virus, leptospirosis, and toxoplasmosis (Garcelon et al. 1992; Roemer et al. 2001a; Clifford et al 2006), but disease resulting from these infectious agents was not found to be a mortality factor until CDV and toxoplasmosis was confirmed in a dead fox on Santa Catalina Island in 1999 (Munson 2010).

The recent finding of ear tumors in Santa Catalina Island foxes, confirmed to be a source of mortality in wild foxes, is of high enough frequency to be considered a concern (Coonan et al. 2010). The first case of this ceruminous gland carcinoma, a rare but aggressive malignant tumor, was diagnosed in 2001. The tumors are primarily confined to the ears of the animals, but in some cases spread to the head and neck region and eventually may **metastasize** (Munson 2010). The disease has been found in all Santa Catalina Island fox age groups, except pups. In 2004, veterinarians found that a high proportion of the adults either had these tumors or showed signs of tissue changes that are possible precursors to tumor development (Munson 2010). The tumors are associated with severe otitis and infections of *Otodectes* (ear mites). *Otodectes* are present in island fox populations on other islands; however, the tumors only occur in Santa Catalina Island foxes.

As of May 2007, parasites have not been confirmed as a mortality source, except for rare cases of complications from *Spirocerca* (nematode) infection (Munson 2010). In a species-wide survey, *Spirocerca* was found in more than half of **necropsied** island foxes, but in most cases appeared to have little effect on individual health (E. Buckles et al. in press). Preliminary genetic analysis and the location of lesions suggest that the *Spirocerca* found in island foxes may be a different species than *S. lupi*, which occurs in domestic dogs and other North American carnivores on the mainland, and is not a major health concern for most island foxes. However, if island foxes are to be brought to the mainland, efforts should be made to prevent transmission of *Spirocerca* from island foxes to mainland carnivores.

Heavy parasite infections by hookworms *(Uncinaria stenocephala)* and a lungworm *(Angiocaulus gubernaculatus)* may have contributed to two mortalities in the San Miguel Island fox subspecies (Coonan et al. 2005c). *Angiocaulus* is not found in other island fox subspecies (Faulkner et al. 2001).

**(d) Population Dynamics.** Even in the absence of catastrophic mortality sources, island fox populations may have fluctuated markedly over time (Laughrin 1980). Residents of Santa Cruz Island occasionally noted periods of island fox scarcity and abundance. Santa Catalina Island fox population levels were low in 1972 and again at low density in 1977 (Laughrin 1980). However, by 1994 the adult Santa Catalina Island fox population was estimated at over 1,300 individuals (Roemer et al. 1994). The San Nicolas Island fox population was considered to be at very low densities in the early 1970s (Laughrin 1980), and may have reached approximately 500 individuals by 1984 (Kovach and Dow 1985, as cited by Wayne et al. 1991b).

Recent demographic analysis indicated that island fox survival was positively related to the previous year's El Niño Southern Oscillations

(ENSO) events in the drier southern islands and negatively related to current and previous year's ENSO events in the wetter northern islands (Bakker et al. 2009; see Appendix 2). Thus, indirect evidence suggests an effect of climate on island fox survival.

## C. HISTORICAL POPULATION STATUS AND OBSERVED DECLINES OF ISLAND FOX POPULATIONS

The four federally listed island fox subspecies (San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, and Santa Catalina Island fox) all experienced precipitous population declines in the latter half of the 1990s (see Table 1) (Coonan et al. 2000, 2005c; Roemer 1999; Roemer et al. 2001a; Timm et al. 2000). Island fox populations on San Miguel, Santa Rosa, and Santa Cruz Islands declined by 90 to 95 percent and, prior to removal of foxes from the wild for captive breeding, were estimated to have a 50 percent chance of extinction over 5 to 10 years (Roemer 1999; Roemer et al. 2001a). Thus, by 1999 researchers considered island fox subspecies on the northern Channel Islands to be critically endangered (Coonan et al. 1998; Roemer 1999), as was the Santa Catalina Island subspecies by 2000 (Timm et al. 2000).

The decline of island foxes in the northern Channel Islands is considered a consequence of **hyperpredation** (Roemer et al. 2001a). The presence of non-native species (feral pigs on Santa Cruz Island and mule deer and elk on Santa Rosa Island) and the absence of bald eagles enabled golden eagles to colonize the islands successfully and prey heavily on island foxes, which evolved in the absence of predators. Evidence of eagle predation included an increase in golden eagle sightings on the northern Channel Islands, discovery of nesting golden eagles (previously unknown from the Channel Islands), and the presence of pig and island fox remains in golden eagle nests (Collins and Latta 2006). A mathematical model of hyperpredation showed that pigs would have been a necessary food source to support a large, resident eagle population (Roemer 1999; Roemer et al. 2001a, 2002) and that as few as six golden eagles could have driven the island fox populations to the lows recorded during the 1990s. In 1999, prior to golden eagle removal efforts, there were estimated to be as many as 27 golden eagles on the northern Channel Islands (Latta et al. 2005).

Based on an analysis of extinction likelihood, Roemer (1999) concluded that if mortality and reproduction continued at rates similar to those observed just prior to intervention, both the San Miguel Island fox and the Santa Cruz Island fox, and likely the Santa Rosa Island fox, would decline to extinction. Successful long-term suppression of golden eagles would likely require removal of the non-native prey base (feral pigs removed from Santa Cruz Island and deer and elk removed from Santa Rosa Island), as well as the successful restoration of bald eagles to the northern Channel Islands (Coonan 2003; Coonan et al. 2005b).

Populations of the San Nicolas Island fox and San Clemente Island fox, the two subspecies that are not federally listed, are each currently estimated to be above 500 individuals, and the populations appear to be stable. The status of these subspecies is discussed in this document as their populations have the potential to serve as surrogates for research required to recover the listed subspecies.

### 1. San Miguel Island

Laughrin surveyed San Miguel Island foxes in the early 1970s (Laughrin 1973). Trap success (number of fox captures per available trap) was high (43 percent) and Laughrin concluded that island fox populations were stable at 2.7 island foxes per $km^2$ (7 per $mi^2$). In the late 1970s, the San Miguel Island fox density averaged 4.6 island foxes per $km^2$ (11.9 per $mi^2$) and the island-wide population was estimated to be 151 to 498 individuals (Collins and Laughrin 1979). In 1993, the NPS began a long-term monitoring program for San Miguel Island foxes, using standardized mark-recapture methods (Roemer et al. 1994). Adult density on two grids was 7.8 island foxes per km2 (20.2 per $mi^2$) and 8.0 island foxes per $km^2$ (20.7 per $mi^2$) in 1993, and the island-wide estimate was about 300 foxes (Coonan et al. 1998). A third grid was added the following year. That grid, the Dry Lakebed grid, recorded the highest density then known for island foxes in 1994 (15.9 island foxes per $km^2$ [41.2 per $mi^2$]) and the island-wide estimate rose to 450 adult foxes.

Annual monitoring documented a substantial decline in the San Miguel Island fox population between 1994 and 1999 (Coonan et al. 1998; Coonan et al. 2000; Coonan et al. 2005c), when the estimated island-wide population steadily and sharply declined, falling to only 15 adults in 1999. In 1999, the NPS brought 14 San Miguel Island foxes into captivity (4 males and 10 females) to initiate a captive breeding program. The only known individual left in the wild at that time, a previously radio-tagged female (Coonan et al. 2005c), was brought into captivity in 2003, but died in December of that year. A necropsy indicated the fox had healed scars on the intercostal muscles between her ribs, suggesting she had survived a predation attempt (Coonan et al. 2004).

The cause of the San Miguel Island fox population decline was almost certainly predation by golden eagles (Roemer 1999; Roemer et al. 2001a; Coonan et al. 2005c). During a radiotelemetry study in 1998 and 1999, six of eight collared foxes died within 4 months, four of which were preyed upon by golden eagles (Coonan et al. 2005c).

### 2. Santa Rosa Island

Laughrin (1980) surveyed the Santa Rosa Island fox population in 1972, reporting a trap success rate of 50.0 percent and a density of 4.2 island foxes per $km^2$ (10.9 per $mi^2$), which coincides with an island-wide population estimate of 898 individuals. No other previous data are available for the Santa Rosa Island fox population except for surveys conducted from 1998 to 2000. Based on island size, Roemer et al. (1994) estimated the island-wide population to be 1,780 adult foxes. More recent trapping data as well as anecdotal evidence suggest that the Santa Rosa Island fox population experienced a decline similar to that of the Santa Cruz Island fox and San Miguel Island fox (Roemer et al. 2001a; Coonan et al. 2005b). Roemer (1999) reported that during 132 trap nights in 1998, only 9 individuals were captured (10 total fox captures), for a trap success rate of 7.5 percent. In 2000 and 2001, the NPS brought the remaining 15 wild Santa Rosa Island foxes into captivity for captive breeding (Coonan and Rutz 2002). No further fox sign was seen on Santa Rosa Island after May 2001 (Coonan et al. 2005b).

Given the proximity of Santa Rosa Island to Santa Cruz and San Miguel islands, the concurrent timing of the population decline, and the presence of golden eagle nests, golden eagle predation was the likely cause of the decline of the Santa Rosa Island fox (Roemer 1999; Roemer et al. 2001a). Golden eagle breeding was confirmed on the island in 2003 (Latta et al. 2005). Both currently and formerly active golden eagle nests were found in two eagle breeding territories, Trap Canyon and Trancion Canyon. Some nests were used in successive years.

Layering of prey remains in the nests indicated that golden eagles had been successfully breeding (fledging young) on Santa Rosa Island since as early as 1997, and island fox remains in the lower layers confirmed predation of eagles upon island foxes (Latta et al. 2005; Collins and Latta 2006). The examined nests on Santa Rosa Island did not contain feral pig remains, indicating that the examined nests were established after pigs were eradicated from the island (post 1992). Examination of golden eagle nests on Santa Rosa Island found remains of island foxes as well as mule deer fawns, island spotted skunks (*Spilogale gracilis amphialus*), and many birds including ravens (*Corvus corax*), mallards (*Anas platyrhynchos*), barn owls (*Tyto alba*), and California quail (*Callipepla californica*) (Latta 2001; Collins and Latta 2006). The prevalence of mule deer fawns in the prey remains underscored their importance for golden eagle breeding on Santa Rosa Island. Golden eagles are also known to eat carrion and carcasses from the annual cull of deer and elk in November and December supported wintering golden eagles. In addition, fawn availability in the spring allowed nesting eagles to successfully fledge young. The non-native deer and elk (*Cervus elaphus*) were managed by the former owners of Santa Rosa Island for a sport-hunting operation. In 2011, large scale efforts to remove the non-native mule deer and elk on Santa Rosa Island were implemented as part of a court settlement (National Parks and Conservation Association v. Kennedy, United States District Court for the Central District of California, No. CV 96-7412-WJR (RNBx) to remove the deer and elk by the end of 2011 (National Park Service 1998). Monitoring in 2012 will verify the success of these efforts (V. Menard, National Park Service, pers comm. 2012). The NPS and a cooperator will remove any remnant deer and elk.

### 3. Santa Cruz Island

Santa Cruz Island is the largest of the Channel Islands and historically supported high densities of island foxes (Laughrin 1973). An early population estimate for the Santa Cruz Island fox was believed to be no more than 3,000 individuals (Laughrin 1971). Between 1973 and 1977, Laughrin (1980) estimated the Santa Cruz Island fox population to be 1,968 individuals based on an average density of 7.9 island foxes per km$^2$ (20.5 per mi$^2$). However, island-wide population estimates extrapolated from annual Santa Cruz Island fox densities on two grids suggest that the population decreased from a high of approximately 1,000 to 1,300 foxes (which is believed to be a more accurate estimate than previous population estimates) in 1993 (Roemer et al. 1994) to an estimated 55 adults in 2001 (Dennis et al. 2001, 2002), and trapping efficiency was 2.9 percent in 1998 (Roemer 1999).

All available evidence indicates the decline of the Santa Cruz Island fox was caused by golden eagle predation (Roemer 1999; Roemer et al. 2001a). From August 1993 to September 1995, golden eagles were linked to 19 of 21 fox mortalities on the western end of Santa Cruz Island. Examination of golden eagle nests on Santa Cruz Island found remains of island foxes as well as island spotted skunks (*Spilogale gracilis amphialus*), feral pigs (*Sus scrofa*), and many birds including ravens (*Corvus corax*), mallards (*Anas platyrhynchos*), barn owls (*Tyto alba*), and California quail (*Callipepla californica*) (Latta 2001; Collins and Latta 2006). Santa Cruz Island foxes were brought into captivity for breeding in 2002 to provide a “safety net” against extinction and offspring to supplement the wild population.

### 4. Santa Catalina Island

Santa Catalina Island fox numbers appear to have fluctuated widely over the past 30 years. During surveys from 1972 to 1977, Laughrin (1980) caught only 2 individuals, and trap success was 3.0 percent, although Propst (1975) caught 55 individuals with a trap success rate of 11 percent. Between 1988 and 1991, average density increased, ranging from 2.6 island foxes per $km^2$ (6.7 per $mi^2$) to 12.7 island foxes per $km^2$ (32.9 per $mi^2$) (Garcelon et al. 1991). The Santa Catalina Island fox population increased to an estimated 1,342 foxes by 1994 (Roemer et al. 1994).

The Santa Catalina Island fox population experienced a catastrophic decline of more than 90 percent from 1999 to 2000. Sightings of dead and dying foxes, retrieval of a single fox carcass infected with CDV, and confirmation of antibodies against CDV in live foxes suggest that this decline may have been due to the introduction of canine distemper to the Santa Catalina Island fox population (Timm et al. 2000). The outbreak occurred principally on the large, eastern portion of the island, which is separated by a narrow isthmus from the smaller western end. Trap success on the eastern side of the island dropped from 26.0 percent in 1998 to 1.0 percent in 1999 and 2000, while remaining stable at approximately 36.0 percent on the western portion. The Santa Catalina Island fox population was reduced to perhaps 100 foxes by 2000, mostly on the west end (Timm et al. 2002).

Currently, there is considerable concern about the high rate of ceruminous gland carcinoma (ear tumors) in Santa Catalina Island foxes and how it might affect the recovery and long-term viability of the population. A 2 year study is being conducted by Munson et al. to understand the risk factors for the cancer and the potential effects these tumors may have on the continuing recovery of the fox population.

Santa Catalina Island has a human population of approximately 4,000, a large population of domestic dogs (*Canis familiaris*), and a considerable number of domestic and feral cats (*Felis catus*). Santa Catalina Island also has the highest degree of human activity and accessibility of any of the Channel Islands (over 1,000,000 visitors per year). These conditions have the potential to affect Santa Catalina Island fox recovery efforts and long-term population stability in ways that are not likely on the other islands.

### 5. San Clemente Island

The San Clemente Island fox has been adversely affected by a history of severe overgrazing, the past use of the island as a bombing range, mortalities from vehicle strikes, and competition from feral cats (Laughrin 1973). The earliest density estimate was 4.2 island foxes per $km^2$ (10.9 per $mi^2$) (Laughrin 1973). Wilson (1976) recorded fox density to be 5.7 island foxes per $km^2$ (14.8 per $mi^2$) and island-wide population size to be 2,000 foxes. Population sampling between 1988 and 1991 found densities of 4.8 island foxes per $km^2$ (12.4 per $mi^2$) to 9.1 island foxes per $km^2$ (23.6 per $mi^2$) (Garcelon et al. 1991). Roemer et al. (1994) found similar densities and estimated an island-wide population of 1,003 foxes. However, Garcelon (1999) estimated that the San Clemente Island fox population ranged between 506 and 875 individuals from 1989 to 1999.

Data from grid trapping indicate that from 1990 to 2000 the San Clemente Island fox population experienced a gradual decline from over 800 foxes to fewer than 600, but the population stabilized, if not increased thereafter, and as of 2004, the population estimate was over 750 foxes (Garcelon 1999, Schmidt et al. 2005a).

Densities in 2004 ranged from 2.4 island foxes per $km^2$ (6.2 per $mi^2$) in grassland to 12.6 island foxes per $km^2$ (32.6 per $mi^2$) in scrub/dune habitats (Schmidt et al. 2005a).

The Navy initiated predator management activities to protect the federally endangered San Clemente Island loggerhead shrike (*Lanius ludovicianus mearnsi*) in 1992. As part of this program, the Navy initially focused on non-native predators (cats and rats), but in 1999 implemented control measures for native predators as well, including the San Clemente Island fox (Department of the Navy 1999). In 1999, the Navy euthanized 13 foxes and relocated 15 to zoos (Garcelon 1999). After 1999, San Clemente Island foxes in San Clemente Island loggerhead shrike breeding territories were shock-collared or captured and held in captivity for the duration of the San Clemente Island loggerhead shrike breeding season. Shock collaring and removal of San Clemente Island foxes to captivity were suspended in 2003. Accidental poisoning from rodenticides used for pest management has also caused San Clemente Island fox mortalities (Munson, 2010); however, there are no records of island foxes having been poisoned on other islands. Feral cats exist on the island in high densities (Phillips and Schmidt 1997) and could be competing with San Clemente Island foxes for prey and may expose them to pathogens.

### 6. San Nicolas Island

Laughrin (1980) reported a density of 0.12 San Nicolas Island fox per $km^2$ (0.3 per $mi^2$) in 1977, which suggested an island-wide estimate of only 7 animals. Laughrin’s reported low trap success rate (4.7 percent) is comparable to the low trap success rates on San Miguel and Santa Rosa Islands at the latter end of the population declines recorded there in the late 1990s. The San Nicolas Island fox population declined to fewer than 30 individuals in the mid-1970s, coincident with the termination of a supplemental feeding program (Laughrin 1980) and an increase in the feral cat population on the island (Kovach and Dow 1982). Using genetic data, Aguilar et al. (2004) estimated that the population had declined to fewer than 10 individuals during the bottleneck. Following the initiation of a feral cat eradication program in 1980, San Nicolas Island fox numbers increased from approximately 120 to 600 foxes in 4 years (Kovach and Dow 1985). As of December 2007, the San Nicolas Island fox population is dense and stable. Grid densities in 2004 ranged from 8.4 island foxes per $km^2$ (21.8 per $mi^2$) to 20.1 island foxes per $km^2$ (52 per $mi^2$), and the island-wide population was estimated to be 548 foxes (Garcelon and Schmidt 2005).

## D. THREATS TO THE SPECIES

Section 4(a)(1) of the Act identifies five major categories of threats, which are considered when a species is listed. These are (a) the present destruction, modification, or curtailment of its range, (b) overutilization for commercial, recreational, scientific, or educational purposes, (c) disease or predation, (d) the inadequacy of existing regulatory mechanisms, and (e) other natural or manmade factors affecting its continued existence. Each of these potential categories of threats is analyzed below.

### Factor A: Present or Threatened Destruction, Modification, or Curtailment of the Species' Habitat or Range

Although it is difficult to quantify the effects of past habitat loss and/or alteration on the status of island foxes, habitat on all islands occupied by island foxes has been heavily affected by livestock grazing, cultivation, and other disturbances. A century and a half of overgrazing by non-native herbivores (e.g., sheep, goats, deer, elk, cattle, pigs, and horses) has resulted in substantial impacts to the soils, topography, and vegetation of the islands (Johnson 1980; Coblentz 1980; Clark et al. 1990; Peart et al. 1994; O'Malley 1994). Much of the native coastal sage scrub, chaparral, and oak woodland habitats have been replaced by other vegetation, especially non-native annual grasses (Brumbaugh 1980; Clark et al. 1990; Klinger et al. 1994). Annual grasslands constitute less preferred habitat for island foxes (Laughrin 1977; Roemer and Wayne 2003) and do not provide cover from predators such as golden eagles (Roemer 1999; Roemer et al. 2001a; Coonan et al. 2005c). In 1987, the California Department of Fish and Game (CDFG) recommended that the island fox retain its classification as threatened under State law because of continued habitat degradation from herbivorous mammals on Santa Rosa, Santa Cruz, Santa Catalina, and San Clemente Islands (California Department of Fish and Game 1987). Since that time, non-native species removal programs have eradicated or reduced the introduced herbivore populations on many of the Channel Islands, including a recent complete removal of over 5,000 feral pigs from Santa Cruz Island (Parkes et al. 2010). Efforts to remove the remaining deer and elk from Santa Rosa Island have likely been successful. Monitoring in 2012 will verify the success of these efforts (V. Menard, National Park Service, pers comm. 2012). The NPS and a cooperator will remove any remnant deer and elk. Nearly all pigs have also been removed from Santa Catalina Island and the island is essentially pig-free (Garcelon et al. 2005).

Although some plant species have increased in number following the removal of non-native herbivores and omnivores from the islands, other aspects of recovery of the native habitats can be slow (Hochberg et al. 1979). In particular, community composition can be altered by the spread of non-native plants that were able to gain a foothold during the period of disturbance. These non-native species continue to invade and modify island fox habitat resulting in lower diversity of vegetation, less diverse habitat structure, and reduced food availability. At present, the indirect effects to the fox through habitat degradation by herbivores continue on Santa Catalina Island. However, effects from past grazing efforts, such as loss of topsoil or spread of non-native species, continue to occur on all islands.

Although it is possible that these habitat changes may have affected island fox at some point in the past, populations remained relatively stable prior to the commencement of golden eagle predation in the mid-1990s and disease in 1999. Also, habitat alteration has not been a hindrance to the rapid recovery of the fox that has taken place.

**Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes**

Island foxes were used in the past for pelts and ceremonial uses by Native Americans (Collins 1991b); however, this is no longer occurring. Therefore, island foxes are not currently exploited for commercial, recreational, scientific, or educational purposes. However, scientists are continually performing recovery efforts through FWS-issued 10 (A)(1)(a) recovery permits. These research activities are not known to be a threat to island foxes.

**Factor C: Disease or Predation**

**Disease**

Infectious diseases from domestic dogs or cats pose a serious threat to all island fox subspecies. As the Santa Catalina Island fox population decline in 1999-2000 illustrates, the potential for introduction of diseases to all island fox populations increases the risk of extinction for these small populations. Many domestic dogs and cats occur on Santa Catalina Island, and dogs occasionally come ashore on the northern Channel Islands, despite the existing prohibition against pets (see Factor D: The Inadequacy of Existing Regulatory Mechanisms). In addition, there are numerous feral cats on Santa Catalina, San Clemente, and San Nicolas Islands.

The catastrophic population decline of Santa Catalina Island foxes during 1999 to 2000 was suspected to be caused by CDV, possibly transmitted from a domestic dog (Timm et al. 2000; 2002) or a wild animal arriving from the mainland. The one Santa Catalina Island fox known to have died from CDV also was concurrently infected with *Toxoplasma* sp., an infectious agent that may have been acquired from cats. The ear inflammation associated with cancer in Santa Catalina Island foxes may be due in part to *Otodectes* mite infections, which is also acquired from feral cats. Other mammals are a potential source of pathogens for island foxes, such as bats infected with rabies.

The disease risk that domestic cats pose to island foxes is also unclear. Pathogen sharing between island foxes and cats is minimal, but not absent (Clifford et al. 2006). Infection with CDV in cats has been previously reported (Appel et al. 1974; Ikeda et al. 2001), and infected cats are capable of shedding CDV into the environment (Munson 2010). Two cats from Santa Catalina Island with CDV antibodies were also seropositive for feline immunodeficiency virus (FIV) and feline leukemia virus (FeLV), which make cats more vulnerable to other diseases and increases shedding of disease organisms, including toxoplasmosis (*Toxoplasma gondii*) (Hoover and Mullins 1991; Pedersen and Barlough 1991; Lin et al. 1992). Island foxes may be exposed to *T. gondii* **oocysts** shed in cat feces, in addition to the tissue cysts in prey items (Tenter et al. 2000).

Toxoplasma has been documented to cause mortality in dogs (Dubey et al. 1989) and a Santa Catalina Island fox (Munson 2010). Concurrent distemper and *T. gondii* infection is associated with a high level of mortality in gray foxes (Davidson et al. 1992; Kelly and Sleeman 2003) and domestic dogs (Brito et al. 2002; Moretti et al. 2006).

Although caliciviruses have been shown to infect a variety of hosts and could possibly be passed between cats and foxes (Smith et al. 1998), calicivirus exposure is not correlated among foxes and cats, and presence of calicivirus antibodies in foxes on islands without cats suggests this interaction is not necessary for fox infection (Clifford et al. 2006). Although competition with cats is likely a more pressing threat to the island fox, the presence of cats on San Nicolas, San Clemente, and Santa Catalina islands may initiate or help propagate an infectious disease epidemic, as pathogens such as distemper and rabies could circulate among these **sympatric** carnivores (Clifford et al. 2006).

All island fox populations have been surveyed for CDV, canine parvovirus, canine adenovirus, canine herpes virus, canine corona virus, leptospirosis, and toxoplasmosis (Garcelon et al. 1992; Coonan et al. 2000; Roemer 1999; Roemer et al. 2001a; Clifford et al. 2006). Antibodies against canine parvovirus and canine adenovirus are highly prevalent in most island fox populations, with the prevalence differing between islands and years (Garcelon et al. 1992; Coonan et al. 2000; Roemer et al. 2001a; Clifford et al. 2006). Differences may be explained in part by differences in test sensitivities in the labs used for these surveys; the most recent survey used a lab with the most sensitive tests (Clifford et al. 2006). This recent survey indicated that Santa Catalina Island fox subspecies apparently has no protection against canine adenovirus (Clifford et al. 2006).

**<u>Predation</u>**

On the northern Channel Islands, golden eagle predation was and continues to be the primary threat to the island fox (Coonan et al. 2005b; T. Coonan, National Park Service, pers. comm. 2007). Golden eagle predation was the cause of 13 of 15 mortalities of wild-born and released island foxes on San Miguel and Santa Rosa Islands from 2003 to 2005 (Coonan and Schwemm 2010). Golden eagle predation accounted for 69 of 92 Santa Cruz Island fox mortalities from December 2000 through June 2007 (Schmidt et al. 2007a; R. Wolstenholme, The Nature Conservancy, pers. comm. 2007).

The onset of golden eagle predation resulted in the population decline of Santa Cruz Island foxes as demonstrated by the decrease in annual survivorship from 83 percent in 1994 to 39 percent in 1995 (Roemer et al. 2001a). San Miguel Island fox survivorship was 12 percent from 1998 to 1999, the tail end of the decline (Coonan et al. 2005c). As golden eagles were removed from the northern Channel Islands, annual Santa Cruz Island fox survivorship increased by 2003 to a level that was previously estimated by demographic modeling to be the minimum necessary for recovery (Roemer et al. 2001b; Coonan et al. 2005b).

There are a number of resident domestic dogs in the interior of Santa Catalina Island and in the leeward coves and camps, many within active island fox territories as well as in the city of Avalon and the town of Two Harbors. In 2005, two deadly interactions occurred between Santa Catalina Island foxes and domestic dogs (J. King, Santa Catalina Island Conservancy, pers. comm. 2011).

**Factor D: Inadequacy of Existing Regulatory Mechanisms**

As identified above, the primary causes of the island fox population declines were attributed to the unprecedented and unnatural levels of predation by golden eagles, the possible spread of canine distemper through the Santa Catalina Island fox subspecies, and the degradation of habitat by introduced herbivores. Federal, State, and local laws have not been sufficient to prevent island fox declines from these causes.

In 1971, the State of California listed the island fox as rare (a designation later changed to threatened), which means that either an incidental take permit is required under the California Endangered Species Act (Section 2081(b)) for otherwise lawful projects or a scientific collecting permit/research memorandum of understanding (Section 2081(a)) is required to take, collect, capture, mark, or salvage for scientific, educational, and non-commercial propagation purposes. State law does not require Federal agencies to avoid or compensate for impacts to the island fox and its habitat.

No regulatory mechanisms have been specifically designed for the protection of the four listed island fox subspecies, except for prohibitions against bringing pets ashore within Channel Islands National Park. Section 2.15 of the superintendent's compendium prohibits pets from all NPS islands, except for guide dogs for visually impaired persons. However, dogs have been used to eradicate pigs from Santa Rosa and Santa Cruz Islands, albeit with implementation of stringent quarantine procedures. Prohibitions against bringing dogs ashore are difficult to enforce (e.g., boaters have been observed bringing pets onshore to all three northern Channel Islands with island fox populations; P. Schuyler, pers. comm. 2006). Health certificates or quarantines are not currently necessary to bring domestic pets to Santa Catalina Island, thus increasing the risk of exposing Santa Catalina Island foxes to disease. On Santa Rosa Island, the current special use permit for the commercial hunting operation allows for island-resident employees of the permittee to have "ranch dogs" on the island. Dogs owned by a non-island resident permittee or guest are allowed in the NPS for periods not to exceed 30 days at a time. All dogs permitted under the special use permit must have proof of vaccination in compliance with Santa Barbara County regulations (only a rabies vaccination is required). In the past several years, Santa Rosa Island ranch dogs have been observed off-leash and uncontrolled in the backcountry of the island (T. Coonan, National Park Service, pers. comm. 2011), suggesting that the special use conditions are not consistently enforced or followed.

Several Federal laws apply to the management of NPS and Navy lands. These laws and guidelines include the National Environmental Policy Act (NEPA) and the Endangered Species Act. The NPS management is further dictated by Department of the Interior policies and NPS policies and guidelines, including NPS guidelines for natural resources management (National Park Service 1991), the Channel Islands National Park General Management Plan (National Park Service 1985), and the National Park Service Organic Act (16 U.S.C. 1, 2, 3, and 4). Both the NPS and the Navy have adequate authority to manage the land and activities under their administration for conservation of the island fox (e.g., feral animal removal). However, in some cases, because of conflicting management concerns, other priorities, and lack of funding, conservation efforts are not proceeding as quickly as would be preferable. In addition to removing golden eagles, their prey base must be removed to prevent recolonization. Feral pigs have been removed from Santa Cruz Island; however, non-native mule deer and elk on Santa Rosa Island are not scheduled to be completely removed until the end of 2011.

San Miguel Island is owned by the Navy, but the NPS has responsibility for management of the natural, historic, and scientific resources of San Miguel Island through a Memorandum of Agreement (MOA) originally signed in 1963, an amendment signed in 1976, and a supplemental Interagency Agreement (IA) signed in 1985. The MOA states that the "paramount use of the islands and their environs shall be for the purpose of a missile test range, and all activities conducted by, or in behalf of, the Department of the Interior on such islands, shall recognize the priority of such use" (Department of the Navy 1963). In addition to San Miguel Island, Santa Cruz Island and Santa Rosa Island lie wholly within the Navy's Pacific Missile Test Center (PMTC) Sea Test Range. The 1985 IA provides for PMTC to have access to and use of portions of those islands, for expeditious processing of any necessary permits by the NPS, and for mitigation of damage to NPS resources from any such activity (Department of the Navy 1985). To date, conflicts concerning protection of sensitive resources on San Miguel Island have not occurred.

Federal protection of golden eagles by the Bald and Golden Eagle Protection Act of 1962, as amended, has increased the golden eagle population in mainland California (B. Walton, Santa Cruz Predatory Bird Research Group, pers. comm. 2004), and golden eagles have expanded their range. The protections extended to golden eagles limit management alternatives; removal of golden eagles requires a depredation permit from the FWS and lethal removal has not been authorized. Such a permit would allow golden eagles to be taken by firearms, traps, or other suitable means except by poison or from aircraft (50 CFR 22.23). A California State law passed in 2003 allows the take of golden eagles and several other "fully protected" species, after a 30-day public notice period, for the purpose of recovering endangered species.

Regulatory mechanisms relevant to control of feral cats are discussed in the section on feral cats below.

**Factor E: Other Natural or Manmade Factors Affecting its Continued Existence**

Several other factors, including competition from introduced species, and stochastic environmental factors may have negative effects on island foxes and their habitats.

**Climate Change**

Climate change was not included as a threat in the listing rule for the island foxes (U.S. Fish and Wildlife Service 2004). Current climate change predictions for terrestrial areas in the Northern Hemisphere indicate warmer air temperatures, more intense precipitation events, and increased summer continental drying (Field et al. 1999, Cayan et al. 2005, IPCC 2007). It is unknown at this time if climate change in California will result in a warmer trend with localized drying, higher precipitation events, or other effects, and predictions of climatic conditions for smaller sub-regions, let alone small offshore islands, remains uncertain.

**Competition with feral cats**

The CDFG, in recommending the retention of the threatened classification of the island fox under State law, cited the presence of competition with feral cats on Santa Catalina Island (CDFG 1987). Feral cats weigh on average twice as much as island foxes and may negatively affect foxes through direct aggression, predation on young, competition for food resources, and disease transmission (Laughrin 1978).

Direct aggression between foxes and cats has been documented in the wild, primarily near leased coves and campgrounds that provide food and shelter (D. Guttilla, Santa Catalina Island Conservancy, pers. comm. 2007). On Santa Catalina Island, frequent capture of cats in canyon bottoms and island foxes higher on slopes (Propst 1975) was attributed to competition and displacement of foxes by cats. On San Nicolas Island, where feral cat and island fox diets overlap by 80 percent, foxes were absent from areas with cat densities exceeding 4 cats per $km^2$ (10 per $mi^2$) (Kovach and Dow 1982; Phillips et al. 2007). After a large number of feral cats were removed from San Nicolas Island, foxes moved into areas previously occupied by cats (Laughrin 1978; Kovach and Dow 1982).

California State law (Food and Agricultural Code 31752.5) prohibits lethal control of feral cats unless cats are held for a minimum of 3 days. On Santa Catalina Island, this law could prevent the CIC from controlling or managing feral cats on the interior of the island, as it does not have adequate facilities to hold cats. The multiple ownership of the island further complicates the application of regulations and other strategies to address the resident feral cat population on the island. A Feral Animal Task Force convened by the City of Avalon, with representatives of the CIC and other island stakeholders, is working to address feral and free-ranging cats in the city and on the rest of the island. San Nicolas and San Clemente Islands, the other two islands with feral cats, are both under federal jurisdiction, and thus are not bound by this State law. Feral cat removal commenced in 2009 on San Nicolas Island (Hanson et al 2010).

**Lack of genetic variation and stochastic environmental factors**

As a population becomes genetically homogeneous, its susceptibility to disease, parasites, and extinction increases (O'Brien and Evermann 1988) as its ability to evolve and adapt to environmental change is diminished (Templeton 1994). The four listed island fox subspecies have all suffered large declines and are at risk of having reduced or low genetic diversity due to the population bottlenecks they have experienced (San Miguel Island fox: Gray 2002; Gray et al. 2001; San Nicolas Island fox: Gilbert et al. 1990; Wayne et al. 1991a; Goldstein et al. 1999) (see Biological Information section for more complete discussion, p. 7).

The extremely small population sizes of the San Miguel Island fox and Santa Rosa Island fox make them vulnerable to extinction. Island endemics have a high extinction risk due to isolation and small population sizes (MacArthur and Wilson 1967), both of which make them more vulnerable to stochastic events such as drought or wildfires (Roemer et al. 2001b; Kohlman et al. 2005). In addition, the lack of genetic variation may make a population less capable of overcoming stochastic events and the relationship between stochastic events and low genetic diversity can become **synergistic**. Therefore, the interrelationship between demographic risk (stochasticity) and genetic risk (low genetic diversity) can increase the risk of extinction.

**Road mortalities**

The lack of fear of human activities in wild island foxes coupled with relatively high levels of vehicle traffic on the southern Channel Islands result in a number of vehicle collisions each year. Death from vehicle collision on roads is the largest known source of mortality on San Nicolas and San Clemente Islands, accounting for approximately 20 to 40 island fox mortalities annually on San Nicolas Island (G. Smith, U.S. Navy, pers. comm. 2007) and a minimum of 26 foxes per year between the years 1991 and 1995 on San Clemente Island (Garcelon 1999). Recently, over 30 foxes per year have died from vehicular trauma on San Clemente Island (Garcelon et al. 2008). On Santa Catalina Island, annual averages of four foxes per year were killed by vehicles from 2003 to 2007 (Schmidt et al. 2004; Schmidt et al. 2005b; IWS 2006; IWS 2007; King and Duncan 2008). Vehicle collisions on the northern Channel Islands are less common due to low traffic volume and the rough dirt roads, which reduce vehicle speed.

**Competition with deer and pigs for food items**

Deer and elk consume fruits that are also preferred by island foxes. For example, mule deer and elk on Santa Rosa Island have been known to heavily browse the federally endangered Santa Rosa Island manzanita (*Arctostaphylos confertiflora*), the fruits of which have been found in island fox feces (T. Coonan, National Park Service, pers. comm. 2011). Similarly, pigs consume a variety of plant and animal items that are also used by island foxes, although recent feral pig eradication programs on both Santa Cruz and Santa Rosa Islands have removed this source of competition.

## 1. Summary of Listing Factors A through E

Listing Factor A, the present or threatened destruction, modification, or curtailment of habitat or range, was not considered a substantial threat at listing. Although habitat alteration has and continues to occur from vegetation type conversion, grazing, and/or fire, the alteration of habitat itself was not identified as the reason for island fox population decline and is not considered a primary threat at this time; however, introducing measures and practices to maintain habitat integrity is recommended for attaining the long-term conservation of the island fox (see LONG-TERM CONSERVATION STRATEGY). Listing Factor B, overutilization for commercial, recreational, scientific, or educational purposes, was not considered a threat at the time of listing and is not considered a threat at this time. The primary threats to the island fox are encompassed within Listing Factor C, pertaining to disease or predation. Predation by golden eagles was one of the primary threats to the island fox at the time of listing and although still considered to be a threat to island fox populations on the northern Channel Islands, the degree of this threat has been decreased as a result of ongoing management practices. At the time of listing it was noted that a disease outbreak is believed to be the cause of the Santa Catalina Island fox population decline. Island fox populations will always be at risk of a disease outbreak; however, the risk potential for disease outbreak can be and has been reduced.

At the time of listing, the following regulatory mechanisms (discussed under Factor D) were not considered to be reasons for island fox decline but were identified to have impeded or precluded the implementation of island fox recovery actions:

- The Bald and Golden Eagle Protection Act of 1962, as amended;
- California Fish and Game Code, section 3511; and
- California Food and Agricultural Code 31752.5.

However, successful recovery strategies have been developed within the constraints of these regulatory controls.

Although not responsible for the dramatic decline in the four island fox subspecies, long-term conservation may be benefitted by addressing the following factors: conducting research on behavioral ecology and reproductive biology; increasing island fox education and outreach activities to reduce anthropogenic impacts; restoring island habitat; and assessing the **demographic** impact of other threats such as mortality from vehicles, competition with feral cats, and emerging disease issues (e.g., ear cancer). These are addressed under LONG-TERM CONSERVATION STRATEGY.

## E. RECOVERY AND CONSERVATION EFFORTS

### 1. Recovery Actions for Listed Island Fox Subspecies

Recent island fox recovery efforts to date have included efforts to ameliorate the impact of golden eagle predation on the three island fox subspecies that occur on the northern Channel Islands and of disease on Santa Catalina Island foxes. All of these efforts have included captive breeding of island foxes to increase each of the four subspecies' populations to viable levels.

#### Northern Channel Islands

In April 1999, the Island Fox Working Group concluded that:

- Predation by golden eagles was the primary mortality factor acting on the island fox populations;
- Disease or parasites may have compounded the effects of predation; and;
- The size of each of these three island fox populations was critically small and the natural reproductive potential and recruitment were low.

At the time, the group agreed that establishing an island fox sanctuary and captive breeding program was necessary to safeguard individuals and to augment natural recruitment into the population.

The NPS began initiating emergency actions in 1999. The objectives were to remove the primary mortality factor affecting island foxes (golden eagle predation), and to recover island fox populations to viable levels via captive breeding. The NPS' island fox recovery strategy (Coonan 2003) utilized demographic modeling (Roemer et al. 2001b) to set the program size and determine the augmentation schedule for captive breeding. To achieve desired annual augmentation rates, the model estimated that an on-island captive population of 20 breeding pairs would be required.

### Translocation of Golden Eagles

Golden eagle translocation from the northern Channel Islands commenced in summer 1999. Golden eagles were trapped and subsequently released in northeastern California. Satellite telemetry affixed to the first 12 translocated golden eagles confirmed that none of the relocated eagles attempted to return to the islands for the 1.5 year life of the transmitter.

Between November 1999 and July 2006, 44 golden eagles, including 22 adults or near adults, were removed from Santa Cruz and Santa Rosa Islands (Latta et al. 2005; Coonan et al. 2010). Most adult and subadult eagles were trapped using a radio-controlled bownet set over dead or live bait (Jackman et al. 1994). Two helicopter net-gunning operations (O'Gara and Getz 1986) on Santa Cruz Island in June and October 2002 failed to capture any golden eagles, due to the difficulty in forcing eagles to ground in the rugged topography and dense vegetation. Ten nestlings were removed by hand from seven different nests (five from Santa Cruz Island and two from Santa Rosa Island) and fostered into mainland golden eagle nests or released via hacking. By mid-2005, seven golden eagles were estimated to remain on the northern Channel Islands, and the removal efforts were yielding diminishing returns. In June 2006, a pair of nesting golden eagles was successfully captured via a net-gun from a helicopter using improved equipment and methods. This pair was removed from Santa Cruz Island and their single chick was removed from the nest by hand (Coonan et al. 2010).

Although there were at least 10 Santa Cruz Island fox mortalities due to golden eagle predation in early 2007, an intensive search in March 2007 failed to locate any golden eagles, thus leaving land managers unsure whether recent deaths were due to a transient or a resident eagle. As of July 2007, there were no known nesting pairs of golden eagles on any of the northern Channel Islands (R. Wolstenholme, The Nature Conservancy, pers. comm. 2007). However, any remaining golden eagles, or additional golden eagles dispersing from the mainland, could continue to prey upon wild and released island foxes, and thereby hamper recovery efforts.

Island fox recovery may ultimately depend on promoting ecological conditions that dissuade golden eagle use of the Channel Islands, including maintaining the islands free of non-native herbivores and restoring bald eagles to the northern Channel Islands. As of the end of 2011, non-native herbivores have been removed from Santa Cruz and San Miguel islands, they have likely been removed from Santa Rosa Island.

Since 2004, 5,036 feral pigs have been removed from Santa Cruz Island, with no individuals known to be remaining on the island (Macdonald and Walker 2007; Morrison et al. 2007). In 2011, large scale efforts to remove the non-native mule deer and elk on Santa Rosa Island were implemented as part of a court settlement (*National Parks and Conservation Association v. Kennedy, United States District Court for the Central District of California, No. CV 96-7412-WJR (RNBx).* Subsequent monitoring will verify success of these removal efforts.

Courchamp et al. (2003) predicted that removal of pigs would cause an increase in golden eagle predation on Santa Cruz Island foxes, reasoning that golden eagles would switch over to preying upon foxes in the absence of pigs, their primary prey. During pig removal, golden eagle predation rates on Santa Cruz Island foxes did not increase (Coonan et al. 2010).

The ongoing efforts to restore bald eagles to the Channel Islands may also provide a deterrent to golden eagle presence on the islands. Sixty-one bald eagles were released on Santa Cruz Island as the result of annual experimental reintroductions of juvenile bald eagles from 2002 to 2006 (Coonan et al. 2010). By early 2007, there were estimated to be at least 40 bald eagles occupying Santa Cruz, Santa Rosa, and Anacapa Islands. In spring 2006, two bald eagle pairs established nests on Santa Cruz Island, and each successfully fledged a single chick (Coonan et al. 2010). These breeding pairs represented the first active and successful bald eagle nests on the northern Channel Islands since the late 1950s (Kiff et al. 1980).

### Captive Breeding

The NPS established a San Miguel Island fox captive breeding facility in 1999 and a Santa Rosa Island fox captive breeding facility in 2000 (Coonan and Rutz 2001). In spring 2002, the NPS in conjunction with TNC established a Santa Cruz Island fox captive breeding facility (Coonan and Rutz 2003). Development of appropriate husbandry methods was guided by a captive breeding sub-group of the island fox working group. Several issues of concern for the northern Channel

Islands captive breeding facilities have been noted in recent years since reproductive success has been low. They include:

- Reproductive failure, perhaps at several stages of the reproductive cycle (i.e., failure to mate, failure to sustain pregnancy, and failure to rear pups);

- Aggression between pen mates; and

- Disease.

Several studies have been conducted or are in progress to address these concerns and to propose management strategies. Carlstead (2006) focused on a historical correlation between reproductive success/failure and the environmental (cage size, complexity, feeding, etc.) and social factors of captive island foxes on all islands. The primary factor affecting reproductive success among females was being wild-born, and having a wild-born mate. Pairs with mate aggression had higher scores for incompatibility (measured by signs of food competition and average distance apart). Differences also occurred due to island fox natal background. Captive-born females were more stressed than wild-born females, captive-born males were more likely to exhibit mate aggression, and wild-born males sired more litters than captive-born males. Pairs with mixed backgrounds (wild-born paired with captive-born) were more likely to lose a litter. Mastitis (inflammation of mammary glands) was more common in pens with high exposure to winds and less perimeter covering. Conversely, pens with more perimeter covering (greater than 27 percent) were less likely to lose litters.

Research evaluating the chronic reproductive failures occurring among captive island foxes on the northern Channel Islands is ongoing (Sovada et al. 2006). Detailed behavioral and physiological observations are being used to identify the stage at which reproductive cycle failure occurs and the behavioral and physiological correlates of the failure. Preliminary results indicate that most reproductive losses occur after mid-gestation but do not yet discriminate among late abortion, stillbirth, and neonatal death. Disease (e.g., mastitis) is likely a contributing factor among some females. Other possibilities are being examined, but underlying causes of failures have yet to be identified. Observations also suggest a high incidence of mate aggression, initiated primarily by males but also by females, which can sometimes result in serious injury. Husbandry changes that could reduce aggression, such as feeding separately, should be instituted.

Additional recommendations from the Island Fox Captive TEG have been made to improve reproduction, including: ensuring that females get sufficient food and water during pregnancy; habituating foxes to their caretakers to reduce stress; adding to the complexity of the enclosures; and building perimeter fences to discourage wild island foxes from interacting aggressively with the captive individuals.

### Parasites

Parasites are not considered a disease threat to wild island foxes; however, parasite burdens in captive individuals have been a cause of concern. For this reason, fecal parasite surveys were recently conducted for captive foxes on San Miguel, Santa Rosa, and Santa Cruz Islands as part of a risk assessment for treating **endoparasites** in captive island foxes (T. Coonan, National Park Service, pers. comm. 2011). A panel convened by USGS-BRD for a risk assessment (Sohn and Thomas 2005) determined that there was little clinical justification for the widespread use of **anthelmintics** in island foxes, given that non-target parasites might be killed by these drugs, with dire consequences for treated foxes. The panel compiled a list of preferred anthelmintics, recommended dosages, and **contraindications**, should treatment for internal parasites be required.

Canine heartworm (*Dirofilaria immitis*) was suspected to be a threat to island foxes because positive *Dirofilaria* antigen tests were documented in four of the six island fox subspecies (San Miguel Island Fox, Santa Cruz Island fox, Santa Rosa Island fox, and San Nicolas Island fox) (Roemer et al. 2000). However, necropsies of over 400 island foxes from all islands have found no evidence of heartworm or heartworm disease (Munson 2010).

### Santa Catalina Island

In response to the catastrophic Santa Catalina Island fox decline that was suspected to be due to CDV, the CIC, which owns and manages 88 percent of the island, contracted with the IWS to develop and implement island fox recovery actions between 1999 and 2005. Beginning in 2006, CIC assumed full responsibility for Santa Catalina Island fox conservation efforts.

CIC and IWS implemented the following four recovery actions (Kohlmann et al. 2005):

1. Intensive mark-recapture sampling to estimate Santa Catalina Island fox population size after the decline was detected;

2. Translocation of juvenile Santa Catalina Island foxes from the dense population on the western end of the island to the eastern end, where foxes had been essentially extirpated;

3. Vaccination of nearly the entire Santa Catalina Island fox population against CDV following trials of vaccine safety and efficacy using captive individuals; and

4. A captive breeding program to augment the Santa Catalina Island fox population.

In 2001 and 2002, 22 juvenile Santa Catalina Island foxes were translocated from the west end of the island to the east end. Survival of these individuals was very high; in 2004, at least 77 percent (n=17) of the translocated foxes were known to be alive, with at least 6 individuals reproducing in their new locations (Coonan et al. 2010). Nearly 50 percent of the translocated foxes started reproducing in their new locations within a year of being moved.

The gray fox, a close relative of the island fox is known to be highly susceptible to CDV and modified live CDV vaccines (Hallbrooks et al. 1981). As a result of this susceptibility, trials were conducted on captive Santa Catalina Island foxes and demonstrated that a new recombinant vaccine (Merial Purevax Ferret®, Merial, Inc., Athens, GA) was both safe and induced antibody production. Following these trials, vaccination of wild Santa Catalina Island foxes began in 2000 (Timm et al. 2000). By the end of 2007, over 1,100 CDV vaccines (some as annual boosters to previously vaccinated individuals) had been administered to Santa Catalina Island foxes (King, Duncan, and Garcelon, in review).

In 2000, the CIC, in conjunction with IWS, established a captive breeding program for Santa Catalina Island foxes. Between 2000 and 2002, 27 Santa Catalina Island foxes were brought into captivity. From 2001 to 2004, 57 individuals were released from captivity, including 37 captive-born pups and 20 of the original wild-captured adults. Survival of captive-born pups was very high (J. King, Santa Catalina Island Conservancy, pers. comm. 2007). In 2003, the first wild pup was born to a released captive-born individual (Clifford 2006). Reproduction by released individuals has continued and both translocated and captive-bred foxes have formed pairs with each other and with resident wild foxes. Based on the high survival (75 percent) of foxes released from 2001 to 2003, and the natural productivity of foxes in the wild, the captive breeding effort on Santa Catalina Island was terminated after the 2004 breeding season.

Although wildlife biologists and conservationists have recommended removal of feral cats from Santa Catalina Island for decades (Anon 1931; Propst 1975; Collins and Martin 1985; Menke and Miller 1985; S. Sillett, Smithsonian Migratory Bird Center, Washington, D.C., pers. comm. 2004; Backlin et al. 2005; Clifford et al. 2006), there is still no long-term, island-wide feral cat management program on Santa Catalina Island. For the last 20 years, the local humane society has practiced trap-neuter-release in Avalon and Two Harbors, where cats are maintained in unconfined feeding colonies ranging from 5 to 75 cats each. These colonies attract reproductively intact cats from surrounding wildland areas and serve as disposal sites for unwanted pets (Guttilla 2007).

During the annual Santa Catalina Island fox trapping efforts from 2004 to 2007, feral cats that were captured incidentally were tested for feline leukemia virus (FeLV) and feline immunodeficiency virus (FIV). Diseased cats were euthanized and healthy cats were sterilized, pit-tagged, and vaccinated for rabies (Guttilla and Stapp 2010). The CIC has continued to collect data on disease prevalence, diet, and feral cat distribution across the island; however, the low trapping-success-rate and difficulty in detecting feral cats has precluded the CIC's ability to accurately calculate feral cat population estimates (Guttilla 2007). Additionally, the introduction of animals, domestic or exotic, to the island has not been regulated and municipal and county regulations are outdated and not enforced. Furthermore, public opposition to lethal control hinders efforts to fundraise for the development and maintenance of a feral cat control program.

## 2. Conservation Efforts for non-Listed Island Fox Subspecies

Conservation efforts are currently underway by the Navy for San Nicolas Island foxes and San Clemente Island foxes, the two island fox subspecies that are not federally listed. To reduce the impact of vehicles as a mortality source, speed limits have been established and education programs have been developed targeting island personnel. The Navy has modified refuse bins, and discourages hand-feeding of island foxes.

Efforts to control feral cats on San Clemente Island began in 1986 (Phillips and Schmidt 1997; U.S. Fish and Wildlife Service 2004). When cat eradication efforts were interrupted for a 6-month interval, cat populations rebounded to pre-control levels and, in some instances, doubled in size (Phillips and Schmidt 1997). However, in areas where control was maintained for three consecutive seasons, cat numbers were reduced by 20 to 50 percent (Phillips and Schmidt 1997). Feral cat removal continues on San Clemente Island (D. Garcelon, Institute for Wildlife Studies, pers. comm. 2011) and San Nicolas Island (Hanson et al. 2010).

The FWS is currently preparing management guidance for island foxes on San Nicolas and San Clemente Islands. The effort includes an evaluation of population status, identification of directions for future research, and recommendations on continuing the following conservation measures:

- Including effects on island foxes in all NEPA documents and mechanisms to minimize effects to island foxes;
- Continuing measures to minimize mortality from vehicle strikes;
- Continuing public awareness campaigns concerning island fox biology and status;
- Reducing potential adverse effects from pest management on the island fox;
- Prohibiting dogs on San Clemente Island or San Nicolas Island;

- Continuing feral cat control on San Clemente Island and San Nicolas Island; and

- Maintaining refuse bin modifications on San Nicolas Island and implementing bin modifications on San Clemente Island.

## 3. Monitoring Efforts

Monitoring island fox populations has been, and will continue to be, a necessary activity. Despite captive breeding programs, golden eagle removal, and other habitat management strategies, island foxes remain at high risk and would remain at some risk even after recovery and de-listing because of the inherently small subspecies population sizes, lack of genetic diversity as a result of the bottleneck, and isolation from other potential population sources. Island fox monitoring has been conducted for a number of years on each of the Channel Islands. However, methods have varied among islands and through the years. Fortunately, data archives from the many years of field work on the various islands provide the resource necessary for designing plans that optimize information return in relation to monitoring effort.

**Monitoring Plans**

A multi-year and highly collaborative monitoring planning process has been completed. The process included:

- Issuance of the Technical Analysis Request (TAR) 2.1 "Development of Population Monitoring Plans for Free-Ranging Island Foxes" to identify island fox monitoring needs (see Appendix 3).

- Development of estimates of demographic parameters by V. Bakker and colleagues through the compilation and robust analysis of island fox population data.

- Development of a population viability analysis (PVA) by D. Doak and V. Bakker (see Appendix 2) to provide the conceptual framework for understanding island fox demographics and threats to island fox viability.

- Development of a set of guidelines by the Island Fox Health TEG (see Appendix 4), which outlines recommendations for monitoring the health of wild island foxes.

- Development of a monitoring plan for San Clemente Island foxes (Spencer et al. 2006) to serve as a framework for TAR 2.1.

The Conservation Biology Institute (CBI) coordinated the development of island-specific monitoring protocols with land managers, TEGs, and statisticians to identify monitoring needs and to develop the most robust and efficient monitoring protocols for each island. Rubin et al. (2007) developed specific monitoring recommendations for each of the four listed subspecies, as well as for the San Nicolas Island fox. Recommendations considered managers' goals, ecological and physical characteristics of the islands as they relate to monitoring needs and constraints, population modeling, evaluation of statistical robustness, and assessment of island representation (see Table 1 in Appendix 3). The monitoring plan for each island includes a scenario for monitoring survival and cause-specific mortality rates and two alternative scenarios for trapping to collect demographic data, such as population size and density (see Appendix 3).

## F. CURRENT STATUS AND TREND

### 1. San Miguel Island fox

In 1999, 14 San Miguel Island foxes were brought into captivity. Only 8 of the 14 founders bred, producing 47 pups from 1999 to 2005. In 2004 when the captive population had increased to 50 foxes, 10 were released, all of which survived through 2005 and 2006. The four females that were released all established breeding territories and produced litters in spring 2005. One wild-born juvenile died from golden eagle predation in January 2006. Annual survival of wild San Miguel Island foxes was 96 percent in 2005 (Coonan and Schwemm, in review). An additional 22 captive San Miguel Island foxes were released to the wild in 2005 and 16 were released in 2006. By the end of 2007, there were a total of 110 San Miguel Island foxes in the wild and 2 foxes in captivity (Coonan 2008). As a result of high reproductive success and continuing high survival rate in the wild, all suitable captive San Miguel Island foxes were released and the NPS discontinued the captive breeding effort in 2007. One older fox considered not suitable for release remained in captivity as of 2008. As of March 2008, predation was a minor source of mortality; there was only one confirmed San Miguel Island fox mortality related to golden eagle predation in the previous 2 years. In early 2008, there were at least 110 San Miguel Island foxes in the wild.

## 2. Santa Rosa Island fox

In 2000, the NPS began bringing Santa Rosa Island foxes into captivity. During 2000 and 2001, all 15 wild Santa Rosa Island foxes were brought into captivity. Thirteen of the 15 founders bred in captivity, and 59 pups were produced from 2000 to 2005. The captive population increased to 56 by 2003, at which time there was an initial release of 12 individuals to the wild. One released fox died from golden eagle predation. A second release, of 13 individuals in fall 2004, resulted in five deaths from golden eagle predation by April 2005.

As a result of the Santa Rosa Island foxes reintroduced in 2003 and 2004, a total of four females bred in the wild in spring 2005 and produced 10 surviving pups (4 males and 6 females). A third release, of 17 foxes, occurred in fall 2005; by March 2006, two of those had died from golden eagle predation, along with two from the 2004 release, and two wild-born pups. Thirteen Santa Rosa Island foxes were released to the wild in 2006.

Annual survival of wild Santa Rosa Island foxes increased from 43 percent in 2004 to 76 percent in 2005, and increased to greater than 90 percent in early 2008 (Coonan and Schwemm, in review). Both released and wild-born Santa Rosa Island foxes produced a total of 26 pups in the wild from 2004 to 2006. As of late 2006, there were 51 Santa Rosa Island foxes in the wild and 28 in captivity, for a subspecies total of 79 foxes (Coonan and Dennis 2007). From September to December 2006, there were 10 Santa Rosa Island fox mortalities, including several released captives. None of the 10 deaths were the result of golden eagle predation. From March 2006 to April 2008, there were no confirmed Santa Rosa Island fox mortalities related to golden eagle predation, and despite two confirmed cases of golden eagle predation on Santa Rosa Island foxes in April 2008, the Santa Rosa Island fox survival rate remained at approximately 90 percent. Additionally, there were at least 62 Santa Rosa Island foxes in the wild and 32 in captivity, for a subspecies total of 94 foxes.

### 3. Santa Cruz Island fox

During 2002 and 2003, the NPS and TNC brought 18 Santa Cruz Island foxes into captivity, leaving about 100 individuals in the wild (Coonan and Rutz 2002; Coonan et al. 2004). Sixteen of the 18 founders bred in captivity, and by summer 2006, the captive population had increased to 81 individuals.

Due to the impact of golden eagle predation on released Santa Cruz Island foxes, few were released from captivity prior to 2006. Seven of 12 captive Santa Cruz Island foxes released to the wild in 2002 to 2003 died from golden eagle predation within 5 weeks of release (Coonan et al. 2005b). No Santa Cruz Island foxes were released in 2004 or 2005. However, survivorship of wild Santa Cruz Island foxes increased during the period of golden eagle removal, suggesting that the removal effort had substantially reduced predation. Annual survival of wild Santa Cruz Island foxes increased from 61 percent in 2001 to 80 percent in 2003 (Coonan et al. 2005b), reaching the level identified by demographic modeling to be necessary for recovery (Roemer et al. 2001b; Coonan 2003).

Due to the higher survival rate coupled with excellent reproduction in the wild in 2004 and 2005, the wild Santa Cruz Island fox population increased to at least 156 known individuals by early 2006, with an island-wide estimate of 207. In the summer and fall of 2006, 55 captive individuals were released, leaving 23 individuals in the breeding facility (Schmidt et al. 2007a). As of March 2007, the wild Santa Cruz Island fox population was estimated to be 264 adults. As of June 2007, 14 of the 56 Santa Cruz Island foxes that were released in 2006 died as a result of golden eagle predation (C. Boser, The Nature Conservancy, pers. comm. 2011).

### 4. Santa Catalina Island fox

By 2002, the minimum population estimate for Santa Catalina Island foxes in the wild was 158, with 94 individuals on the west end and 64 on the east end (Kohlmann et al. 2005). A population viability analysis by IWS in 2003 estimated that east and west populations of 150 foxes each would be large enough to have acceptably low probabilities of extinction due to stochastic effects (Kohlmann et al. 2005). By 2004, the minimum number of known foxes was 271, and the captive breeding and translocation efforts were terminated (Schmidt et al. 2005b). The Santa Catalina Island fox population estimate was 509 individuals in 2006 and increased to an estimated 572 individuals in 2007 with reproduction and pup survival continuing to remain high (King, Duncan, and Garcelon, in review).

Due to the continued potential for a disease outbreak, vaccination of wild Santa Catalina Island foxes continues. Starting in 2005, both CDV and rabies vaccinations were administered. During the summers of 2006 and 2007, 25 individuals of **age class** 1 or above were radio collared and left unvaccinated to serve as "disease sentinels" (J. King, Santa Catalina Conservancy, pers. comm. 2007). During 2007, slightly more than 60 percent of the estimated total population was vaccinated against CDV (J. King, Santa Catalina Conservancy, pers. comm. 2007), and 82 percent of all marked foxes that were captured in the wild between 2000 and 2007 have been vaccinated at least once (King, Duncan, and Garcelon, in review).

The high prevalence of ear tumors and associated mortalities in Santa Catalina Island foxes is a continuing cause of concern.

### 5. San Clemente Island fox

Recent trends in annual population estimates are lacking for the San Clemente Island fox because surveys were not conducted in 2005 or 2006. Coonan (2003) reported an estimated population size of 680 adult San Clemente Island foxes. Schmidt et al. (2005a) reported an estimated population size of 396 individuals in 2004, after applying density corrections. San Clemente Island fox survey, monitoring, and population estimate methods changed in 2007. The 2007 San Clemente Island fox population estimate, based upon the new methodologies, ranges from 302 individuals to 727 individuals (Garcia and Associates 2008). As of 2009/2010 the population was estimated to be 714 individuals (Coonan 2011).

### 6. San Nicolas Island fox

Currently, the San Nicolas Island fox population is dense and relatively stable (Garcelon and Schmidt 2005). The annual rate of population increase ($\lambda$, or lambda) from 2000 to 2004 was estimated to be 1.06. In 2006, the island-wide population estimate was 542 individuals (Schmidt et al. 2007b). Ongoing San Nicolas Island fox conservation efforts include population monitoring, prey monitoring, and a recent social ecology study (B. Cypher, California State University, Stanislaus, Endangered Species Recovery Program, pers. comm. 2007). An automated telemetry monitoring system is also being developed and tested.

### 7. Summary

On the northern Channel Islands, golden eagle removal and captive breeding programs with reintroductions have reduced the risk of extinction for the San Miguel Island fox, Santa Rosa Island fox, and Santa Cruz Island fox and have allowed the re-establishment of wild populations on Santa Rosa and Santa Cruz islands. Although there is still some predation by golden eagles, there have been no golden eagle nests on the northern Channel Islands since 2006 which has likely been attributable to the efforts associated with golden eagle capture and translocation, feral pig eradication, and reintroduction of bald eagles.

On the southern Channel Islands, the two non-listed subspecies (the San Clemente Island fox and San Nicolas Island fox), appear to be stable. Following disease mitigation efforts, the Santa Catalina Island fox population is increasing, however, the threat posed by ear tumors to Santa Catalina Island foxes are of continued concern. In addition, potential threats to Santa Catalina Island foxes, San Nicolas Island foxes, and San Clemente Island foxes include competition with feral cats, vehicle strikes, and the introduction of infectious disease.

# II. Recovery Strategy

The two primary known threats that resulted in the listing of the four subspecies of island fox (San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, and Santa Catalina Island fox) as endangered were predation by golden eagles and the transmission of disease. Although not responsible for the dramatic decline in the four island fox subspecies, long-term conservation may be benefitted by addressing the following factors: conducting research on behavioral ecology and reproductive biology; increasing island fox education and outreach activities to reduce anthropogenic impacts; restoring island habitat; and assessing the **demographic** impact of other threats such as mortality from vehicles, competition with feral cats, and emerging disease issues (e.g., ear cancer). These are addressed under Long-term Conservation Strategy section. Additionally, because the population size of each island fox subspecies is small, they are threatened by stochastic events and the effects of low genetic diversity. Recovery of each subspecies will be achieved by removing, or substantially reducing, known threats, such as predation by golden eagles and disease-related mortality, and increasing populations to viable levels for long-term survival of each subspecies. The strategy of this recovery plan is to continue the current recovery efforts and to improve and expand recovery actions as necessary. Recent and ongoing island fox recovery efforts include: removing golden eagles from the northern Channel Islands; reducing the threat of disease; breeding island foxes in captivity and reintroducing them to the wild; monitoring wild island fox populations; reintroducing bald eagles; and the removal of non-native species (e.g., non-native herbivores).

The majority of golden eagles have been removed from the northern Channel Islands, yet predation by golden eagles remains a threat to the long-term recovery of wild island fox populations, including in the southern Channels Islands. Thus, golden eagle monitoring and removal efforts need to continue, and management agencies need to be prepared to respond if and when new golden eagles arrive on any of the Channel Islands. The successful reintroduction of bald eagles has resulted in the re-establishment of the first bald eagle nests on the northern Channel Islands in over 50 years and their continued presence is expected to be a long-term deterrent to the potential recolonization of the islands by golden eagles.

On Santa Catalina Island, a majority of island foxes have now been vaccinated for CDV and rabies. However, domestic dogs remain in contact with Santa Catalina Island foxes and the potential for new disease transmission from dogs, cats, and other anthropogenic sources exists throughout the Channel Islands. Reducing the threat of disease will require avoiding the introduction of new pathogens or novel strains of existing pathogens to the Channel Islands.

Captive breeding and reintroduction of all four endangered island fox subspecies has occurred on the Channel Islands as a means to provide a safe haven from predators and to augment the wild populations. Increasing the wild populations to levels with **vital rates** that minimize the risk of extinction is integral to island fox recovery. All foxes that were in captivity on Santa Catalina Island and the three northern Channel Islands have been reintroduced to the wild. On Santa Cruz Island, all captive individuals were reintroduced to the wild in 2007.

Quick and accurate detection of possible future declines is paramount to maintaining viable island fox populations. Wild populations need close monitoring to gauge progress toward recovery criteria and also to detect any future declines. We encourage frequent communication among the land managers in an effort to achieve the most cost-effective and rapid recovery of each island fox subspecies while standardizing recovery efforts as much as possible using the best available science and peer review. Management activities need to include:

- Monitoring island foxes over the long-term;
- Adapting as new information is gathered;
- Ensuring that population declines can be detected rapidly;
- Determining causes of decline; and
- Eliminating causes of decline as rapidly as is feasible.

The Channel Islands' ecosystems have been significantly altered and degraded over the past 2 centuries as a result of the introduction of non-native plant and animal species, unsustainable livestock grazing, and other anthropogenic activities (e.g., chemical pollution). Additional and increasing human impacts on all islands as well as managed efforts to restore ecosystems (e.g., removal of invasive species on some islands, including deer, elk, pigs, sheep, rats, and cattle), will likely continue to affect the island ecosystems, with both positive and negative effects on island fox recovery.

# III. Recovery Goals, Objectives, and Criteria

## A. RECOVERY GOAL

The goal of this recovery plan is to recover the San Miguel Island fox, the Santa Rosa Island fox, the Santa Cruz Island fox, and the Santa Catalina Island fox so they can be delisted (removed from the List of Threatened and Endangered Species) when existing threats to each respective subspecies have been ameliorated such that their populations have been stabilized and have increased. The interim goal is to recover these subspecies to the point that they can be downlisted from endangered to threatened status.

## B. RECOVERY OBJECTIVES

Recovery objectives are discrete targets that, when taken together, comprise the conditions under which a species may be delisted. Recovery objectives identify mechanisms for measuring progress toward and achieving the recovery goal.

Achieving the recovery goal requires: 1) increasing the population size and demographic rates to self-sustaining levels; and 2) reducing or eliminating the current threats to the survival of each subspecies.

### 1. Recovery Objective 1:

Wild island fox populations exhibit demographic characteristics consistent with long-term viability.

### 2. Recovery Objective 2:

Land managers are able to respond in a timely fashion to potential and ongoing predation by golden eagles, to potential or incipient disease outbreaks, and to other identified threats.

For an island fox subspecies to be considered for downlisting from endangered to threatened status, recovery objective 1 is met.

For an island fox subspecies to be considered for delisting, recovery objective 1 and recovery objective 2 are met.

Each listed subspecies may be considered for downlisting or delisting independently of the other subspecies.

## C. RECOVERY CRITERIA

An endangered species is defined in the Endangered Species Act as a species that is in danger of extinction throughout all or a significant portion of its range. A threatened species is one that is likely to become endangered within the foreseeable future throughout all or a significant portion of its range. When we evaluate whether or not a species warrants downlisting or delisting, we consider whether the species meets either of these definitions. A recovered species is one that no longer meets the Act's definitions of either threatened and endangered. Determining whether a species should be downlisted or delisted requires consideration of the of the same five categories of threats (*i.e.*, the five threat factors, A-E) which were considered when the species was listed and which are specified in section 4(a)(1) of the Endangered Species Act.

The island fox recovery criteria are measurable standards for determining whether an island fox subspecies has achieved its recovery objectives and may be considered for downlisting or delisting. The recovery criteria presented in this draft recovery plan represent our best assessment of the conditions that would most likely result in a determination that downlisting and/or delisting of the San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, or the Santa Catalina Island fox is warranted. Achieving the prescribed recovery criteria is an indication that the species is no longer threatened or endangered. Because an actual change in status (downlisting or delisting) requires a separate rulemaking process that is based on an analysis of the same five factors that were analyzed at listing, the Recovery Criteria below pertain to and are organized by these factors. Each Recovery Criterion applies to all four subspecies, except where noted otherwise.

**Factor A: The present destruction, modification or curtailment of its habitat or range.**

We believe that, if the threats under factors C and E are ameliorated, then the improvements in the habitat that are expected to occur with removal of herbivores responsible for habitat degradation may be a long-term benefit to the island fox but is not necessary for the recovery of the island fox subspecies. Therefore, we are not proposing recovery criteria under this factor.

**Factor B: Overutilization for commercial, scientific or educational purposes.**

Overutilization is not currently known to be a threat for this species. Therefore, no recovery criteria are necessary for this factor.

**Factor C: Disease or predation.**

To address recovery objective 2, disease and predation pressures must be reduced. This will have been accomplished if the following have occurred:

C/1: Golden eagle predation:

a. To reduce the threat of extinction to the San Miguel Island fox, the Santa Rosa Island fox, and the Santa Cruz Island fox, the rate of golden eagle predation is reduced and maintained at a level that is no longer considered a threat to island fox recovery through development of a golden eagle management strategy. The strategy will be developed by the land manager(s) in consultation with the FWS and will include review by the appropriate IRT Technical Expertise Group or the equivalent. This strategy includes:

- Response tactics to capture golden eagles responsible for island fox predation;
- Tactics to minimize the establishment of successful nesting golden eagles;
- An established island fox monitoring program that is able to detect an annual island fox predation rate caused by golden eagles of 2.5 percent or greater, averaged over 3 years (Bakker and Doak 2009); and
- An established mortality rate or population size threshold that, if reached due to golden eagle predation, would require the land manager(s) to bring island foxes into captivity for safety.

b. The golden eagle prey base of deer and elk is removed from Santa Rosa Island.

At present, golden eagles are not known to prey upon Santa Catalina Island foxes. If mortality as a result of golden eagle predation becomes a threat to the Santa Catalina Island fox, implement the above measures as necessary.

C/2: A disease management strategy is developed, approved, and implemented by the land manager(s) in consultation with the FWS and includes review by the appropriate IRT TEG or the equivalent. This strategy includes:

- Identification of a portion of each population that will be vaccinated against diseases posing the greatest risk for which vaccines are safe and effective. Vaccinations to be provided and numbers vaccinated will be developed in consultation with appropriate subject-matter experts;
- Identification of actual and potential pathogens of island foxes, and the means by which these can be prevented from decimating fox populations;
- Disease prevention;
- A monitoring program that provides for timely detection of a disease outbreak, and an associated emergency response strategy as recommended by the appropriate subject-matter experts; and
- A process for updating the disease strategy as new information arises.

**Factor D: Inadequacy of existing regulatory mechanisms.**

We believe that if the threats under factors C and E are ameliorated, then additional regulatory mechanisms (beyond existing ones) are not necessary. Therefore, we are not proposing Recovery Criteria under this factor.

**Factor E: Other natural or manmade factors affecting its continued existence.**

To address both recovery objective 1 and 2 for each of the four subspecies, the subspecies must be protected from other natural or manmade factors known to affect their continued existence. This will have been accomplished if the following has occurred:

E/1: An island fox subspecies has no more than 5 percent risk of quasi-extinction over a 50-year period (addresses objective 1). This risk level is based on the following:

- Quasi-extinction is defined as a population size of ≤30 individuals.
- The risk of extinction is calculated based on the combined lower 80 percent confidence interval for a 3 year running average of population size estimates, and the upper 80 percent confidence interval for a 3 year running average of mortality rate estimates.
- This risk level is sustained for at least 5 years, during which time the population trend is not declining.

This risk-based recovery criterion is based on models developed separately for each listed subspecies. A description of the models can be found in Appendix 2.

# IV. Recovery Program

## A. RECOVERY ACTION NARRATIVE

The actions identified below are those that, in our opinion, are necessary to bring about the recovery of island foxes. These actions are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions. Each action has been assigned a priority as follows:

Priority 1: An action that is taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2: An action that is taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3: All other actions necessary to provide for full recovery of the species.

Unless otherwise indicated, all actions are to be conducted for each listed subspecies of island fox.

### 1. Reduce mortality and maintain productivity for each subspecies of island fox to sustainable levels.

Two major mortality factors have been identified, golden eagle predation and disease. Therefore, most actions identified below address these two factors.

1.1. Reduce rate of golden eagle predation and maintain at a level that is no longer considered a threat to island fox recovery. Implement and maintain an active monitoring/response program for golden eagles as needed.

1.1.1. Develop and implement a formal golden eagle management strategy (Priority 1).

This should include plans for monitoring, control, removal, and contingency in case of golden eagle return after removal. The golden eagle management strategy should have the flexibility to adapt to new information and changing conditions, and to evaluate all known means of capturing golden eagles, or suppressing their ability to prey on island foxes.

1.1.2 Monitor for golden eagle activity (Priority 2).

Conduct annual monitoring at minimum during the nesting season to detect any resident golden eagles. Monitoring should include aerial and ground surveys as needed and training for all field staff to identify and report all eagle sightings. Maximize all opportunities to locate golden eagles whenever any field activities are undertaken.

1.1.3 Remove golden eagles to maintain the Channel Islands free of resident golden eagles.

If golden eagles are seen or signs are found of their presence, steps should be taken to determine whether capture and removal to the mainland is necessary. Continue to consult with eagle experts for additional techniques to capture and/or manage golden eagles. Develop new methods to improve golden eagle capture as needed.

Continue golden eagle trapping and removal efforts until all resident golden eagles have been removed from the northern Channel Islands.

1.1.3.1 Complete initial removal of golden eagles from northern Channel Islands (Priority 1).

Continue golden eagle trapping and removal efforts until all resident golden eagles have been removed from the northern Channel Islands

1.1.3.2 Control resident golden eagles on the Channel Islands, as needed, after 1.1.3.1 above is complete to sustain island fox populations (Priority 1).

1.1.3.3 Identify and manage any activities or food sources that are attractants for golden eagles. Minimize the availability of food resources for golden eagles to inhibit successful establishment of territories/reproduction and to direct eagles toward capture baits. Conduct additional removals of golden eagles from any island as needed (Priority 3).

1.1.3.4 Conduct research needed to understand and eliminate golden eagle residency on the Channel Islands (Priority 3).

Such research could include food habit studies and genetic analyses to determine how frequently golden eagles immigrate from the mainland.

1.2 Avoid introduction of new pathogens, or novel strains of existing pathogens, to the Channel Islands by restricting or regulating movements of wild and domestic animals to the islands.

The small size of island fox populations means that infectious disease has an unusually high potential to cause population crashes or even extinction. Island foxes have a history of exposure to infectious disease, but may be immunologically naïve to pathogen strains that are endemic to the mainland but absent from the Channel Islands.

Additional details and guidance for this recovery action provided by the island fox health TEG can be found in Appendix 4.

1.2.1 The ban on bringing pets to Channel Islands National Park, and to TNC land on Santa Cruz Island, should be well-publicized and strictly enforced (Priority 1).

1.2.2 Where there is a clear benefit to bringing domestic dogs to the northern Channel Islands, the quarantine guidelines established for dogs brought to Santa Cruz Island to assist with pig eradication efforts should be followed (see Appendix 5) (Priority 1).

1.2.3 Movement of non-native species or carcasses to the northern Channel Islands should be avoided wherever possible (Priority 3).

1.2.4 The potential for pathogen introduction to Santa Catalina Island from the movement of wild and domestic mammals should be reduced to the extent practicable (Priority 1).

1.2.5 Develop a management strategy for responding to new introductions of animals to the Channel Islands (Priority 3).

1.3. Implement preventative management to avoid extinction or quasi-extinction of wild populations in the event of devastating epidemics.

PVA models suggest that the probability of extinction in the face of a rabies or CDV epidemic could be substantially reduced by maintaining a "vaccinated core" of animals. This approach involves maintaining a small number of animals protected from infection by vaccination. These animals act as a "safety net," intended to survive any epidemics that occur and then to form a founder group from which subsequent recovery may occur. PVA models suggest that, assuming vaccination is 100 percent protective, maintaining a "vaccinated core" of 80 to 100 vaccinated individuals per island fox subspecies dramatically reduces the probability of population extinction, even when there is a comparatively high (10 percent) probability of a rabies epidemic in any one year (Schwemm 2007).

Additional details and guidance for this recovery action provided by the island fox health TEG can be found in Appendix 4.

1.3.1 Test safety of, and antibody response to, vaccination in captive island foxes under appropriate research protocols.

1.3.1.1 Conduct CDV vaccination trials by administering two vaccinations at different bodily locations on island foxes during a single vaccination event (Priority 1).

1.3.1.2 Assess the efficacy of standard inactivated rabies vaccines in producing an antibody response in island foxes (Priority 1).

1.3.1.3 Vaccines against canine parvovirus and adenovirus should be tested on island foxes (Priority 3).

1.3.2 On each island, maintain vaccination cover for rabies and CDV in at least 80 to 100 island foxes (Priority 1).

On islands where wild fox populations number fewer than 100 individuals, all island foxes should be vaccinated. On Santa Cruz Island, vaccination should be focused in one or two localized areas. On Santa Catalina Island, vaccination efforts should be concentrated around the city of Avalon (where disease introduction is most likely to occur) and around the isthmus (where infection could potentially pass between the eastern and western subpopulations).

When a vaccine is first introduced, a proportion of vaccinated individuals should be radio-collared on each island to allow determination of whether vaccination has any negative consequences for island foxes in the absence of an epidemic.

1.4 Establish monitoring and response strategies to detect and manage infectious disease threats to island fox population persistence.

Additional details and guidance for this recovery action provided by the island fox health TEG can be found in Appendix 4.

1.4.1 Monitor to detect disease-related mortality.

1.4.1.1 Using radiotelemetry, monitor a sample of foxes on each island to detect fox mortalities (Priority 1).

Island foxes selected for radio-collars as part of routine monitoring (as opposed to after a vaccine is first introduced) should not be vaccinated; this allows them to act as sentinels of infection, allowing early detection of future epidemics.

See Recovery Action Section 3.0 and Appendix 3 for more details.

1.4.1.2 Any island foxes that are found dead should be collected and shipped or frozen immediately for necropsy (Priority 1).

1.4.1.3 Any island fox appearing ill or acting in an abnormal manner should be reported immediately, quarantined, and closely monitored (Priority 1).

1.4.1.4 Other carnivores sick or dead from causes other than trauma should be reported and closely monitored (if alive) or collected for necropsy (if dead) (Priority 3).

1.4.2 Annually collect blood samples from a proportion of island foxes on all islands to evaluate ongoing disease risks to island fox populations (Priority 2).

1.4.3 Develop strategies for responding to island fox deaths from infectious diseases known to represent serious threats to the persistence or recovery of the wild populations.

1.4.3.1 All island managers should develop an emergency response strategy for dealing with disease incidents relevant to island foxes (Priority 1).

1.4.3.2 A single case of rabies, confirmed by pathology or virus isolation, should trigger management response strategy (in development) (Priority 1).

1.4.3.3 A single case of canine distemper, confirmed by pathology or virus isolation, should trigger management response strategy (in development) (Priority 1).

1.4.3.4 A single case of disease caused by parvovirus or adenovirus, confirmed by pathology or virus isolation, should prompt more intensive monitoring for sick or dead island foxes (Priority 2).

1.5. Conduct research to understand and evaluate the threats to island foxes posed by other infectious and noninfectious diseases, and develop management strategies.

1.5.1 Complete on-going investigations of the demographic consequences and etiology of the ear tumors prevalent in Santa Catalina Island foxes to determine whether this disease poses a significant threat to this fox population (Priority 2).

1.5.2 Expand research on the role of co-pathogens and viral strain variation to provide better insights into the circumstances of a disease outbreak under which management interventions are, and are not, warranted (Priority 2).

1.6.2 1.5.3 Conduct further research as appropriate on other infectious and noninfectious diseases that appear likely, on the basis of pathological and demographic analyses, to threaten island fox populations (Priority 2).

## 2. Manage captive island fox populations for recovery.

Captive populations of island foxes have been critical to the species' conservation and can continue to be important in the recovery and long-term conservation (see Long-term Conservation section) of the four listed subspecies. Captive breeding must be conducted in accordance with the FWS' Captive Propagation Policy. Foxes were initially brought into captivity to prevent extinction from the threat of golden eagle predation on the northern Channel Islands, and the threat of disease on Santa Catalina Island. Captive reproduction has ensured that the island foxes did not go extinct and has contributed to recovery of wild populations by providing individuals for release as the current threats have been brought under control. On-island captive breeding can be phased out as wild populations recover, but the long-term persistence of island foxes (see Long-term Conservation section) may benefit from redundant, genetically diverse, and sustainable mainland populations of one or two subspecies.

2.1 Manage the on-island captive populations of island foxes to augment the wild populations.

2.1.1 Continue captive management of island foxes as necessary to provide individuals for release (Priority 1).

2.1.2 Assuming golden eagle predation and disease risks remain low, continue annual release of island foxes from the captive facilities until such releases are no longer necessary to augment wild populations (Priority 1).

2.1.3 Use genetic, demographic, and appropriate behavioral and physiological characteristics, together with established PVA models, to determine which individuals to release and which to retain annually, such that an appropriate level of genetic diversity of the remaining island fox captive populations is retained while captive breeding is ongoing (Priority 1).

2.1.4 Continue to monitor released island foxes and use this information to modify release strategies (e.g., release locations and timing) (Priority 2).

2.1.5 Once captive breeding is no longer necessary on each island, maintain captive facilities such that a predetermined number of island foxes could be recaptured and maintained in captivity in the event of a new catastrophic threat (Priority 1).

2.1.6 While any on-island captive populations still exist, continue to identify and implement improved husbandry practices to ensure the health of captive island foxes, improve reproductive success, and enhance the success of released foxes (Priority 1).

2.1.7 Continue to maintain an island fox studbook and continue to use the studbook to aid decisions on fox pairing and release (Priority 2).

## 3. Establish island fox monitoring strategies.

Monitoring of island fox populations has been, and will continue to be, a crucial activity. Given the inherent risk of small insular populations, robust monitoring of island fox populations and their threats is a key component of recovery and long-term conservation. Such long-term monitoring strategies should incorporate the best established methods to track population dynamics and to detect and understand the causes of population declines in a timely manner. To that end, an effective monitoring strategy should be able to address each of the following monitoring objectives:

- Tracking the status of island fox recovery, particularly relative to recovery criteria;
- Guiding island-specific management decisions in a timely manner;
- Refining parameter estimates for population viability analyses and facilitating cross-island comparisons; and
- Monitoring to detect a potential future and/or current catastrophic population decline.

3.1 Develop and implement a monitoring strategy for each listed island fox subspecies to detect population declines and determine population trends (Priority 1).

Monitoring parameters need to be targeted for the purpose of tracking and determining recovery. These parameters include:

- Mortality rates (with associated cause-specific mortality rates);
- Population trend (e.g., lambda); and

- Population size, possibly relative to a required minimum population size as informed by PVA.

These parameters would provide information necessary for the evaluation of extinction risk based upon the PVA and aid in determining the current level of risk to an island fox population (Recovery Criterion 1) as well as aiding in determining the progress towards recovery. These parameters were presented and reviewed at the second PVA Workshop convened at U.C. Davis in December 2006, including refinement of parameters in the context of recovery criteria, to identify desired precision levels. Based on this workshop, the following parameters and associated precision levels have been chosen for the purpose of tracking and determining recovery:

- Annual estimate of island-wide population size, with an 80 percent confidence interval.

- Annual estimate of mortality, with an 80 percent confidence interval and cause-specific mortality rates sufficient to detect a rate of eagle predation of 2.5 percent or greater (Bakker and Doak 2009). In addition, these data would provide a means of surveying for disease and facilitate health research and vaccine efficacy tests.

- Estimate of trend in population size, which can be estimated either from annual abundance estimates or from population models. This estimate has no targeted precision; rather the precision of the trend estimate would be determined by the precision of the population estimates and possibly by precision of mortality rates (see Appendix 3).

3.2 Ensure island fox population information is comparable across the islands to the greatest extent possible (Priority 3).

Recommendations for achieving this include collecting, storing, and managing data using standardized protocols.

# V. Implementation Schedule

The table that follows is a summary of scheduled actions and costs for recovery of the island fox. The table serves as a guide for meeting the objectives discussed in Parts II, III, and IV of this recovery plan. The table includes the following five elements:

**1. Priority.** The actions identified in the implementation schedule are those that, in our opinion, are necessary to bring about the recovery of these species. However, the actions are subject to modification as dictated by new findings, changes in species status, and the completion of recovery actions. The priority for each action is given in the first column of the implementation schedule, and is assigned as follows:

Priority 1. An action that is taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2. An action that is taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

Priority 3. All other actions necessary to provide for full recovery of the species.

**2. Action Number and Description (from narrative outline).** The action number and description are extracted from the step-down narrative found in Part IV of this recovery plan. Please refer back to this narrative for a more detailed description of each action.

**3. Action Status or Duration.** The action duration column indicates the number of years estimated to complete the action, if known, or labeled as a project if it is a discrete action, or whether it is a planned or ongoing action. Project, planned, and ongoing actions are defined as follows:

Project. A discrete action that will be implemented on a one-time only basis, or until no longer required.

| | |
|---|---|
| Planned (Continual). | Action will be implemented on a regularly scheduled basis once it is begun. |
| Ongoing. | Action is currently being implemented and will continue until no longer necessary for recovery. |

**4. Stakeholders.** In the table, we have identified agencies and other parties that we believe are primary stakeholders in the recovery process. Stakeholders are those agencies who may voluntarily participate in any aspect of implementation of particular actions listed within this recovery plan. Stakeholders may voluntarily participate in project planning or provide funding, technical assistance, staff time, or any other means of implementation; however, stakeholders are not obligated to implement any of these actions. The list of potential stakeholders is not limited to the list below; other stakeholders are invited to participate in recovery of the island fox. The following abbreviations are used to indicate the stakeholder for each recovery action for the four subspecies of island fox:

AZA. Association of Zoos and Aquariums

CDFG. California Department of Fish and Game

CIC. Santa Catalina Island Conservancy

FWS. U.S. Fish and Wildlife Service

NPS. National Park Service

TNC. The Nature Conservancy

UNIV. University or academic researchers

**5. Cost Estimates.** Cost estimates for the first 5 years after release of the recovery plan are shown for some of the recovery actions. Costs of some recovery actions cannot be estimated at this time. Costs of developing and implementing management and protection plans will vary with local circumstances and details of individual plans.

Cost estimates are as follows:

Year 1:  $2,761,000 + to be determined

Year 2:  $1,301,000 + to be determined

Year 3:  $1,169,500 + to be determined

Year 4:  $1,167,500 + to be determined

Year 5:  $1,216,500 + to be determined

5-Year TOTAL:  $7,615,500 + to be determined

**Table 3. Implementation schedule for the draft recovery plan for four subspecies of island fox**

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 1 | 1.1.1 | Develop and implement a formal golden eagle management strategy. | Project | FWS<br>NPS<br>TNC | 40 | 40 | | | | |
| 1 | 1.1.2 | Monitor for golden eagle activity. | Ongoing | FWS<br>NPS<br>TNC | 550 | 110 | 110 | 110 | 110 | 110 |
| 1 | 1.1.3.1 | Complete initial removal of golden eagles from northern Channel Islands. | Completed | FWS<br>NPS<br>TNC | – | – | – | – | – | – |
| 1 | 1.1.3.2 | Control resident golden eagles on the Channel Islands, as needed, to sustain island fox populations. | Ongoing | FWS<br>NPS<br>TNC | 225 | 45 | 45 | 45 | 45 | 45 |
| 3 | 1.1.3.3 | Conduct research needed to understand and eliminate golden eagle residency on the Channel Islands. | Project | FWS<br>NPS<br>TNC<br>UNIV | 350 | 100 | 100 | 50 | 50 | 50 |
| 1 | 1.2.1 | The ban on bringing pets to Channel Islands National Park, and to TNC land on Santa Cruz Island, should be well-publicized and strictly enforced. | Ongoing | NPS<br>TNC<br>FWS | 37.5 | 7.5 | 7.5 | 7.5 | 7.5 | 7.5 |
| 1 | 1.2.2 | Where there is a clear benefit to bringing domestic dogs to the northern Channel Island(s), the quarantine guidelines established for dogs brought to Santa Cruz Island to assist with pig eradication efforts need to be followed (see Appendix 5). | Planned | NPS<br>TNC<br>FWS | TBD | | | | | |

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 3 | 1.2.3 | Movement of other mammals or carcasses to the northern Channel Islands should be avoided wherever possible. | Ongoing | CDFG FWS NPS TNC | NA | | | | | |
| 1 | 1.2.4 | The potential for pathogen introduction to Santa Catalina Island from the movement of wild and domestic mammals should be reduced to the extent practicable. | Planned/ Ongoing | CDFG CIC FWS | 5 | 1 | 1 | 1 | 1 | 1 |
| 3 | 1.2.5 | Develop a management strategy for responding to new introductions of animals to the Channel Islands. | Project | CDFG CIC FWS NPS TNC | 47 | 43 | 1 | 1 | 1 | 1 |
| 1 | 1.3.1.1 | Conduct CDV vaccination trials by administering two vaccinations at different bodily locations on island foxes during a single vaccination event. | Planned | CIC FWS NPS TNC UNIV | 40 | 12.5 | 12.5 | 5 | 5 | 5 |
| 1 | 1.3.1.2 | Assess the efficacy of standard inactivated rabies vaccines in producing an antibody response in island foxes. | Project | CIC FWS NPS TNC UNIV | 48 | 38 | 10 | | | |
| 3 | 1.3.1.3 | Vaccines against canine parvovirus and adenovirus should to be tested on island foxes. | Project | FWS UNIV | 10 | 10 | | | | |

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 1 | 1.3.2 | On each island, maintain vaccination cover for rabies and CDV in at least 80 to 100 island foxes. | Planned | CIC<br>FWS<br>NPS<br>TNC | 675 | 135 | 135 | 135 | 135 | 135 |
| 1 | 1.4.1.1 | Using radiotelemetry, monitor a sample of foxes on each island to detect fox mortalities. | Ongoing | CIC<br>NPS<br>TNC | 750 | 150 | 150 | 150 | 150 | 150 |
| 1 | 1.4.1.2 | Any island foxes that are found dead should be collected and shipped or frozen immediately for necropsy. | Ongoing | CIC<br>NPS<br>TNC | 125 | 25 | 25 | 25 | 25 | 25 |
| 1 | 1.4.1.3 | Any island foxes appearing ill or acting in an abnormal manner should be reported immediately, quarantined and closely monitored. | Ongoing | CIC<br>NPS<br>TNC | 6 | 2 | 1 | 1 | 1 | 1 |
| 3 | 1.4.1.4 | Other carnivores sick or dead from causes other than trauma should be reported and closely monitored (if alive) or collected for necropsy (if dead). | Planned | CIC<br>NPS<br>TNC | 5 | 1 | 1 | 1 | 1 | 1 |
| 2 | 1.4.2 | Annually collect blood samples from a proportion of island foxes on all islands to evaluate ongoing disease risks to island fox populations. | Planned | CIC<br>NPS<br>TNC | 365 | 73 | 73 | 73 | 73 | 73 |
| 1 | 1.4.3.1 | All island managers should develop an emergency response strategy for dealing with disease incidents relevant to island foxes. | Project | CIC<br>NPS<br>TNC | 113 | 63 | 50 | | | |
| 1 | 1.4.3.2 | A single case of rabies, confirmed by pathology or virus isolation, should trigger management response. | Project | CIC<br>NPS<br>TNC | TBD | | | | | |

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 1 | 1.4.3.3 | A single case of canine distemper, confirmed by pathology or virus isolation, should trigger management response. | Project | CIC<br>NPS<br>TNC | TBD | | | | | |
| 2 | 1.4.3.4 | A single case of disease caused by parvovirus or adenovirus, confirmed by pathology or virus isolation, should prompt more intensive monitoring for sick or dead foxes. | Project | CIC<br>NPS<br>TNC | TBD | | | | | |
| 2 | 1.5.1 | On-going investigations of the demographic consequences and etiology of the ear tumors prevalent in Santa Catalina Island foxes should be completed to determine whether this disease poses a significant threat to this fox subspecies. | Ongoing | CIC<br>FWS<br>UNIV | 45 | 30 | 10 | 3 | 1 | 1 |
| 2 | 1.5.2 | Expand research on the role of co-pathogens and viral strain variation to provide better insights into the circumstances of a disease outbreak under which management interventions are, and are not, warranted. | Project | CIC<br>FWS<br>NPS<br>TNC<br>UNIV | 75 | 50 | 10 | 5 | 5 | 5 |
| 2 | 1.5.3 | Further research should be conducted as appropriate on other infectious and noninfectious diseases that appear likely, on the basis of pathological and demographic analyses, to threaten island fox populations. | Project | CIC<br>FWS<br>NPS<br>TNC<br>UNIV | 150 | 50 | 25 | 25 | 25 | 25 |
| 1 | 2.1.1 | Continue captive management of island foxes as necessary to provide individuals for release. | Completed | NPS | – | – | – | – | – | – |

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 1 | 2.1.2 | Assuming golden eagle predation and disease risks remain at low levels, continue annual release of foxes from the captive facilities until such releases are no longer necessary to augment the wild populations. | Completed | NPS | – | – | – | – | – | – |
| 1 | 2.1.3 | Use genetic, demographic, and appropriate behavioral and physiological characteristics, together with established PVA models, to determine which individuals to release and which to retain annually, such that an appropriate level of genetic diversity of the remaining captive populations is retained while captive breeding is ongoing | Completed | AZA NPS | – | – | – | – | – | – |
| 2 | 2.1.4 | Continue to monitor released island foxes and use this information to modify release strategies (e.g., release locations and timing). | Ongoing/ Planned | NPS | 250 | 50 | 50 | 50 | 50 | 50 |
| 1 | 2.1.5 | Once captive breeding is no longer necessary on each island, maintain captive facilities such that a predetermined number of island foxes could be recaptured and maintained in captivity in the event of a new catastrophic threat. | Ongoing | CIC NPS | 75 | 20 | 3 | 1 | 1 | 50 |
| 1 | 2.1.6 | While any on-island captive populations still exist, continue to identify and implement improved husbandry practices to ensure the health of captive island foxes, improve reproductive success, and enhance the success of released foxes. | Completed | CIC NPS | – | – | – | – | – | – |

| Action Priority | Action Number | Action Description | Action Status or Duration | Potential Stakeholders | Total Cost Estimate (in $1,000 units) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 5-Year | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| 2 | 2.1.7 | Continue to maintain an island fox studbook and continue to use the studbook to aid decisions on fox pairing and release. | Ongoing | AZA<br>CIC<br>NPS | 25 | 5 | 5 | 5 | 5 | 5 |
| 1 | 3.1 | Develop and implement a monitoring strategy for each listed island fox subspecies to detect population declines and determine population trends. | Ongoing | CDFG<br>CIC<br>FWS<br>NPS<br>TNC | 1,525 | 305 | 305 | 305 | 305 | 305 |
| 3 | 3.2 | Ensure island fox population information is comparable across islands to the greatest extent possible. | Planned | CDFG<br>CIC<br>FWS<br>NPS<br>TNC | 5 | 1 | 1 | 1 | 1 | 1 |

TBD = Costs to be determined
NA = No cost is anticipated

# VI. Long-term Conservation Strategy

The long-term conservation strategy identifies actions that would further the conservation of the island fox. At this time, these activities are not essential for preventing extinction and are not required for downlisting or delisting a particular island fox subspecies; however, these activities could substantially enhance the long-term conservation of the species and may also increase our scientific understanding of the island fox. In the event that an island fox subspecies is recovered and delisted, completion of these actions could provide conservation benefits that would prevent future decline of the species.

We have identified the following long-term conservation actions:

- Establish a mainland captive island fox population to conduct research to better understand fox behavior, ecology and reproduction, and disease and vaccine efficacy.
- Increase public awareness to reduce potential threats from anthropogenic activities.
- Assess the demographic impact of other threats such as mortality from vehicle strikes and competition with feral cats.
- Restore island habitat.
- Establish conservation agreements.

### 1. Establish a mainland captive island fox population to conduct research to better understand fox behavior, ecology and reproduction, and disease and vaccine efficacy.

The establishment of a mainland captive island fox population could contribute to island fox conservation through improved opportunities for research and increased opportunities for educating and affecting public attitudes towards the island fox which could result in greater support for island fox conservation programs. A mainland population might also provide a source population for re-colonization should the subspecies become extinct.

A mainland captive island fox population can serve as an accessible source of individuals for research. There are still many unanswered questions concerning the best husbandry and management methods for successful captive breeding. Mainland facilities are more accessible to veterinary and husbandry expertise and more efficient in terms of costs and logistics. The ability to conduct research trials on the islands is limited. Furthermore, such trials will not be possible on the islands in the near future because existing captive breeding facilities will likely close. The source for a mainland captive population can come from any of the existing island fox subspecies, including non-listed subspecies, although TAR 3.6 "Assessment of the potential benefits and costs of long-term captive populations on the mainland and/or islands" suggests that the Santa Cruz Island fox population would be the best choice, because this subspecies has the most genetic diversity and the island population is recovering rapidly.

Given that space and resources are limited to establish redundant populations for each of the four endangered subspecies of island fox it is unrealistic to expect to have a redundant population of each subspecies. In the event of a catastrophic loss, two alternatives exist to repopulate an island: 1) use individuals from another existing wild island fox subspecies; or 2) use individuals from an established mainland captive population where one, or at most two, subspecies would be maintained on the mainland.

Below is a list of activities that would benefit island fox research:

1.1 Develop a captive mainland island fox population for research and educational outreach purposes.

- Develop a long-range strategy for establishing a mainland captive island fox population in accordance with the FWS' Captive Propagation Policy.

  This strategy should strive to maximize the genetic and demographic viability of the mainland populations while avoiding or minimizing any detrimental impacts to wild populations. See Appendix 6 for steps necessary in establishing a mainland captive population.

- Identify and prioritize research questions that could be addressed using the captive mainland population.

This might be achieved by forming a standing advisory committee to review proposals, prioritize projects, and help identify funding sources. Selected research questions include: 1) determining the best management practices for husbandry to maximize reproduction and ensure animal welfare (e.g., mate selection, housing requirements); 2) biomedical research on captive populations to help eliminate and/or control disease threats to the wild and captive island fox populations; and 3) development of management and husbandry techniques to maximize fox survival post-release (see Appendix 7 for details).

## 2. Establish, expand and continue island fox education and outreach programs.

The main objectives of the education and outreach programs include: Reduction of threats that are under the control of island managers, residents, visitors, and regulatory agencies; increased public support for existing and future programs dealing with island fox population recovery, threat abatement, habitat improvement, and sustainable use of habitats; and development of a long-term support system, including fund-raising activities, to support island fox recovery efforts.

Below is a list of such activities that would aid in island fox education and outreach:

2.1 Develop and establish on-island education programs.

- Provide island fox information to residents, staff, and visitors to the Channel Islands (Priority 3).

- On each island with foxes, develop self-guided kiosks, exhibits, and/or programs to provide current information about island foxes and recovery efforts (Priority 3).

2.2 Develop and establish mainland education programs.

- Identify educational and outreach opportunities that could be addressed using the captive mainland population.

- Develop strong collaborations with existing organizations (e.g., Friends of the Island Fox, Inc.) working on mainland education programs.

- All zoos that house island fox populations, particularly those in southern California, should include a robust education program.

- Mainland island fox exhibits should provide accurate and timely information on the status of and threats to island foxes.

- Develop island fox presentations, traveling exhibits and publications to be presented or deployed in mainland schools, symposia, meetings and other venues.

- Develop school curriculum materials on island foxes, consistent with California education standards that can be used in mainland classrooms prior to student field trips to an island.

2.3 Develop cost effective methods for enhancing public awareness and support for island fox recovery.

- Utilize the media to enhance public awareness and support for island fox recovery programs.

- Develop an appropriate set of professional evaluation tools (Measures of Success) to help managers and agencies evaluate the effectiveness of the general and island-wide education and awareness programs.

- Develop an effective set of communication venues for island fox researchers and land managers.

2.4 Continue and expand, as appropriate, the annual island fox conference, and develop a web-based literature depository and/or a regular newsletter or list-server to enhance communication.

- Establish a web-based island fox literature library where educators and researchers can access information about the island fox.

- Develop and publish an annual report on island fox recovery and conservation efforts.

### 3. Assessing the demographic impact of other threats such as mortality from vehicle strikes, competition with feral cats, and emerging disease issues (e.g., ear cancer).

The threat from anthropogenic sources such as vehicles and disease highlights the need to increase public awareness of island fox recovery issues. A mainland population could serve as the basis for outreach programs to inform and engage the zoo-going public about threats to the Channel Islands and their inhabitants. Education and outreach programs are being developed and should continue to expand their impact in making the public aware and motivated to support island fox recovery.

Small populations, including many island endemics, have lower genetic diversity than larger populations and may suffer from increased inbreeding and inbreeding depression. Small populations are also more prone to demographic stochasticity, including random variation in population birth and death rates that can lead to population "booms" and "busts." These "busts" have great potential to result in extinction. Furthermore, small populations are more vulnerable to annual variation in environmental conditions (e.g., drought). Such variation has been identified as an important factor influencing island fox demography (see Appendix 2).

### 4. Restoring island habitat.

Ultimately the long-term survival and viability of the island fox may depend on maintaining and restoring some of the composition, structure, and function of native ecosystems on the islands that have been altered in the past 150 years. These actions include promoting ecological conditions that dissuade golden eagle use of the Channel Islands.

Preserving and restoring native ecosystem structure and function while preserving significant cultural resources and providing for recreational opportunities are explicit management goals of the NPS; TNC and CIC share similar goals. While island foxes were no doubt components of formerly intact ecosystems, there is no assurance that those intact ecosystems were optimal in terms of sustaining the largest populations of foxes. For example, the conversion of some shrublands to grasslands during the ranching period may have provided for increased populations of island foxes. On the other hand, in the face of aerial predation, shrublands may confer differential advantage to foxes. Consequently, ecosystem restoration activities will need to respond adaptively to the response of island fox populations.

The goal of ecosystem restoration is to maintain and restore native ecosystem composition, structure, and function in a manner that does not compromise island fox recovery. Ultimately, activities will restore native ecosystem integrity in a manner that enhances island fox recovery and long-term conservation, while protecting other listed and sensitive species. Because each of the Channel Islands differs significantly in their native ecosystem structure and composition, maintenance and restoration should be tailored to each island individually.

Below is a list of activities that would aid in ecosystem recovery:

4.1 Identify non-native plants and animals that may compromise island fox viability and evaluate their impact on fox populations. Removal or control should be conducted if impacts are significant or potentially significant and the means for practicable removal or control exists.

4.2 Minimize the likelihood of new non-native species introductions through the use of education, regulation, sanitation, and best management practices.

4.3 Reintroduce or enhance native ecosystem elements and processes that have been lost or compromised as a result of anthropogenic activities.

4.4 Prevent disturbance of island ecosystems' native structure and function to the extent practicable.

4.5 Minimize, to the extent feasible, mechanical, chemical, or acoustic impacts to island foxes and den sites during restoration activity, especially during the breeding and pup-rearing seasons.

4.6 Protect natural water supplies in island fox habitat from damage, and avoid eliminating island fox water sources.

4.7 Monitor island fox food resources during restoration efforts, including native animal prey populations and plant resources.

- If these food resources change adversely during restoration activity, manage adaptively to provide for adequate food resources during the restoration period.

4.8 Monitor and adaptively manage distribution of habitat types on each island during restoration activities to assure sufficient ecosystem services for island foxes, such as hunting habitat, resting habitat, and protective cover (against predation).

- Although island foxes have historically occurred in nearly all vegetation types, maintaining the native array of these types provides a buffer against unanticipated ecological catastrophe.

4.9 Where non-native species may represent a supportive habitat function (food, cover), plan ecosystem restoration actions to assure alternate prey or other resources provided by the non-native species are available and sufficient during the restoration period.

4.10 As naturally-ignited landscape fire on the Channel Islands is rare and most ecosystem elements, including island foxes, have not been selected for fire resilience, minimize the likelihood of anthropogenic fire.

## 5. Establishment of Conservation Agreements.

Even with successful mitigation of current threats and the recovery of island fox subspecies to viable population levels, the intrinsically small population sizes of the subspecies and their insular vulnerabilities subject the different subspecies to the continued threat of catastrophic decline from any number of causes.

To reduce the potential for future catastrophic population declines and the consequent need to relist the San Miguel Island fox, the Santa Rosa Island fox, the Santa Cruz Island fox, or the Santa Catalina Island fox post-recovery:

A Conservation Management Agreement is developed between the land manager(s) and the FWS to address long-term conservation needs. The agreement should be designed to respond effectively to any future significant population decline and include:

- The land manager's strategy and commitment to continue monitoring island fox subspecies such that any substantial population decline is detected in a timely manner; and
- The land manager's strategy to address the long-term conservation of island foxes at the time of proposed delisting.

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# VIII. Appendices

The following appendices provide information related to island fox recovery efforts. Recommendations provided in some of these the appendices were based upon the best information available at the time they were developed; however, we are aware that as new information arises, a previous recommendation may need to be revised or new recommendations may need to be developed.

These appendices are also provided to compile many sources of information related to island fox recovery into one location.

# A. APPENDIX 1: CURRENT AND FORMER MEMBERS OF THE ISLAND FOX RECOVERY TEAM AND PRIMARY AUTHORS OF THIS RECOVERY PLAN

**Island Fox Recovery Coordination Group**

| | |
|---|---|
| Brian Cypher | California State University Stanislaus, Endangered Species Recovery Program |
| Carlos de la Rosa | Santa Catalina Island Conservancy |
| David Graber | National Park Service |
| Devra Kleiman | Zoo-Logic, LLC |
| Eric Morrissette | U.S. Fish and Wildlife Service |
| Peter Schuyler | Independent Biologist |
| Rebecca Shaw | The Nature Conservancy |
| Dale Steele | California Department of Fish and Game |
| Rosie Woodroffe | University of California at Davis, Department of Wildlife Conservation Biology |

## Chairs of the Island Fox Technical Expertise Groups

Captive Population Management:

Peter Siminski The Living Desert

Ecosystem Restoration:

Lyndal Laughrin Santa Cruz Island Reserve

Fox Health:

Linda Munson University of California at Davis

Genetics:

Colleen Lynch AZA Population Management Center

Golden Eagle:

Sandy Vissman U.S. Fish and Wildlife Service

Population Modeling:

Kathy Ralls Smithsonian National Zoological Park

Reintroduction:

Dan Blumstein University of California at Los Angeles

Wild population management:

Scott Morrison The Nature Conservancy

## Integrated Island Fox Recovery Team

Andelt, William
Asa, Cheryl
Bakker, Vickie
Baldwin, Sandra
Bauman, Karen
Blumenshine, Karen
Blumstein, Dan
Boyce, Jennifer
Breen, Kevin
Bremner-Harrison, Sam
Brock, Kelly
Calkins, Betsy
Carlstead, Kathy
Charlton, Josh
Chatfield, Jennifer
Christianson, Matt
Clifford, Deana
Collins, Paul
Comrack, Lyann
Coonan, Tim
Coppelli, Susan
Cory, Coleen
Cypher, Brian
Daily, Marla
Daugharty, Kirin
Davis, Heather
Dearborn, Keri
de la Rosa, Carlos
Denney, Richard
Dennis, Mitchell
deSpain, Forrest
Detrich, Phil
Doak, Dan
Drake, Lisa
Dratch, Peter
Duncan, Calvin
Efford, Murray
Faulkner, Kate
Ferrara, Francesca
Fox, Jodi
Gabriel, Mourad
Galipeau, Russell
Garcelon, David
Graber, Dave
Gray, Melissa
Green, Michele
Guglielmino, Angela
Guieb, Ruben
Guttilla, Darcee
Haight, Bob
Hall, Lynn
Hanna, Shari
Hill, Karl
Horiszny, Sheri
Hudgens, Brian
Johnson, Heather
Keitt, Brad
Kimble, Katie
King, Julie
Kleiman, Devra

Kunkel, Kyran
Latta, Brian
Laughrin, Lyndal
Lea, Amanda
Leslie, Elaine
Little, Annie
Littlefield, Ben
Lynch, Colleen
Mazet, Jonna
McCrary, Mike
Meyer, Pat
Miller, Phil
Morrison, Scott
Morrissette, Eric
Moxie, Jeff
Munson, Linda
Orrock, John
Patton, Sharon
Power, Paula
Powers, Robyn
Provinsky, Stephanie
Ralls, Katherine
Randall, Kara
Ruane, Martin
Roemer, Gary
Rubin, Esther
Sanchez, Jessica
Sandhaus, Estelle
Schuyler, Peter
Schwemm, Cathy
Scott, Eric
Scott, Kim
Shaw, Rebecca
Sharpe, Peter
Siminski, Peter
Smith, Grace
Smith, Tessa
Sovada, Marsha
Steele, Dale
Swarts, Hilary
Thomas, Nancy
Varsik, Alan
Vermeer, Lotus
Vickers, Winston
Vissman, Sandy
Watson, Debbie
Wayne, Bob
Widmer, Ali
Wilkerson, Cynthia
Willett, Mark
Williams, Ian
Wolstenholme, Rachel
Woodroffe, Rosie

## B. APPENDIX 2: DISCUSSION OF THE RISK-BASED RECOVERY CRITERION

Models were developed for the San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, and Santa Catalina Island fox to gain insight into the factors influencing the risk of extinction for each subspecies population over a 50 year time period (Bakker et al. 2009). The model is a two-stage (pup v. non-pup; i.e., considering only two life stages, pups (< 1 year old) and animals referred to as adults (> 1 year old)) stochastic matrix model. Demographic rates are simulated based on established relationships with environmental conditions such as golden eagle numbers, island fox densities, and weather conditions. The model carefully incorporates uncertainty in our knowledge of island foxes into model predictions.

Based on the output of model simulations, it is possible to predict the risk of a population reaching quasi-extinction using adult mortality rate and adult population size. These risk predictions can be plotted as isoclines (see Figures 1a through 1d: a graph has been created for each subspecies). Each isocline identifies the risk of the particular subspecies reaching the determined quasi-extinction level of 30 foxes over the determined timeframe of 50 years based on current mortality rates and population sizes.

To use these graphs to assess attainment of recovery criterion 1, one plots the average adult mortality rate against the average adult population size calculated over three (3) years along with their 80% confidence intervals. From the location of this point relative to the risk isoclines, one would be able to identify the current predicted risk of quasi-extinction for the subspecies based upon the model. Recovery criterion 1 is attained when the plotted point and its mortality and population size confidence intervals lie entirely below the isocline delineating 5% risk of quasi-extinction.

Management to avoid quasi-extinction rather than true extinction (e.g., zero individuals) helps account for uncertainty in models, especially uncertainty associated with population dynamics at small sizes, and it focuses efforts on maintaining populations at levels at which management action is most feasible. This approach is used commonly in estimating risk for a population (Morris and Doak 2002), and has been used in the development of risk-based recovery criteria (e.g., Northern right, Fin, and Sperm whales). The choice of an appropriate threshold depends on a range of biological and socio-political factors (Burgman et al. 1993). A quasi-extinction threshold of 30 individuals was selected for each of the federally listed island fox subspecies populations.

Note: The isoclines provided are to serve for illustrative purposes and to provide a visual reference to estimate the risk of quasi-extinction based upon the appropriate parameters. The actual risk of quasi-extinction is to be calculated.

The isoclines associated with the risk of quasi-extinction for each subspecies should be adjusted with new information, as necessary.

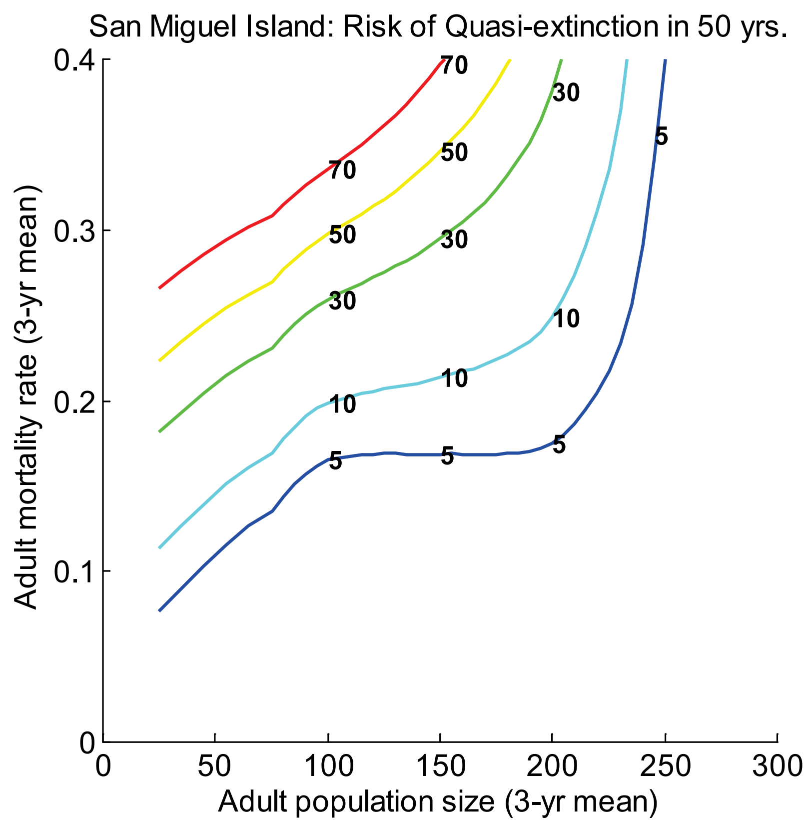


***Figure 1a: Risk of the San Miguel Island population reaching quasi-extinction using adult mortality rate and adult population size.***

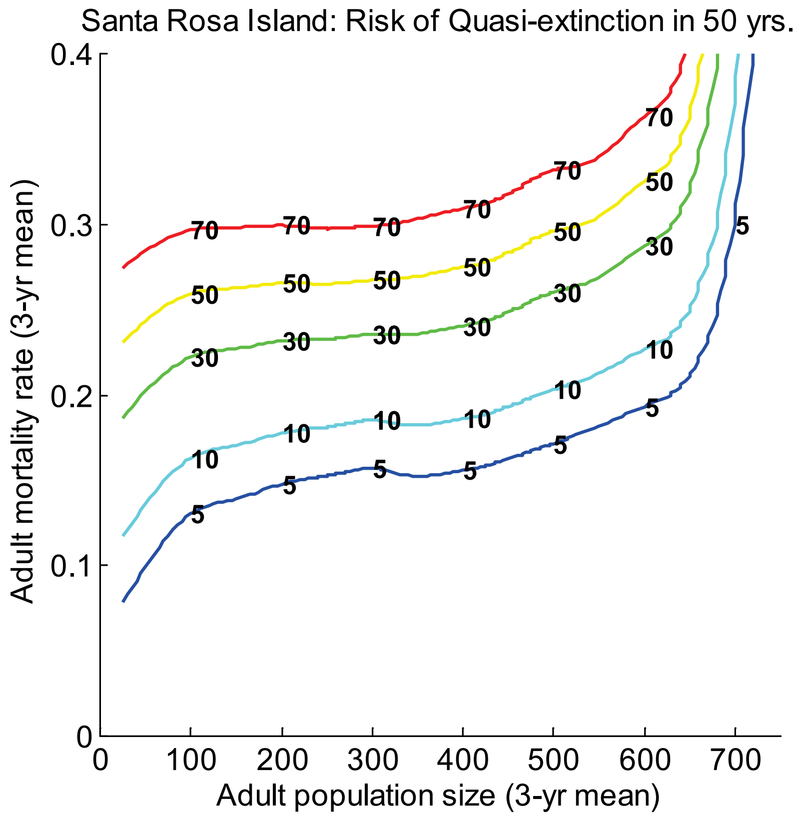


***Figure 1b: Risk of the Santa Rosa Island population reaching quasi-extinction using adult mortality rate and adult population size. Because the PVA model was not parameterized using data from Santa Rosa Island, this contour plot assumes that foxes on Santa Rosa Island have survival rates similar to foxes on Santa Cruz and San Miguel islands and reproductive rates similar to those on San Miguel Island.***

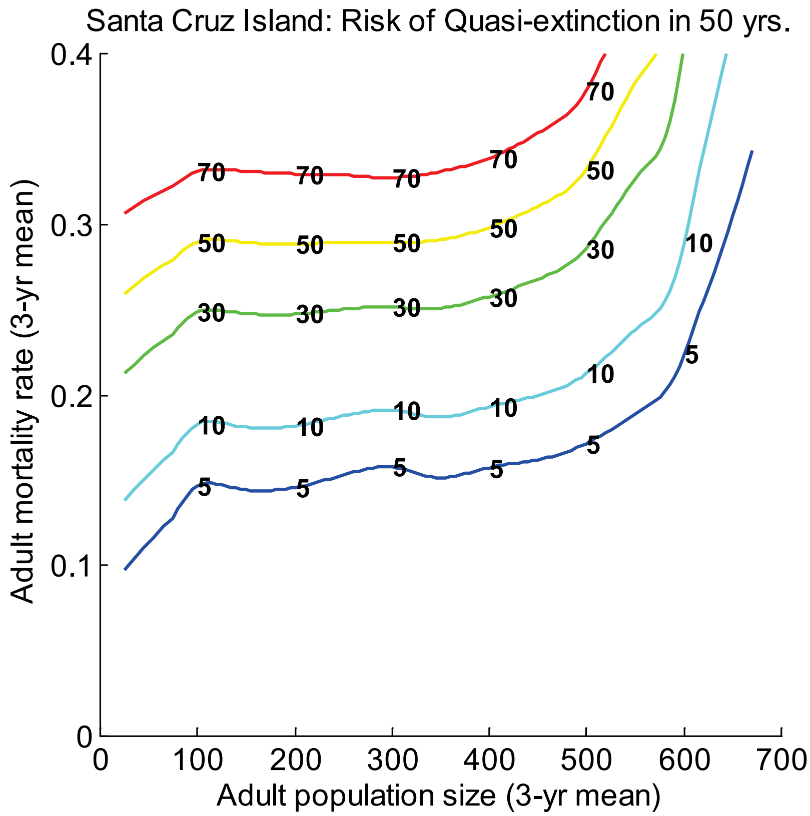


***Figure 1c: Risk of the Santa Cruz Island population reaching quasi-extinction using adult mortality rate and adult population size.***

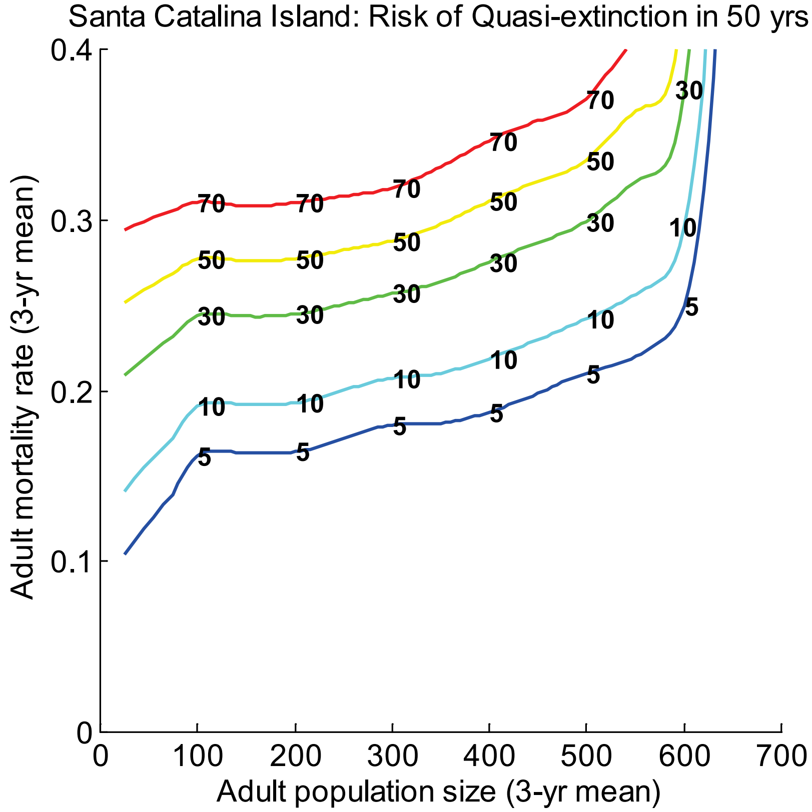


***Figure 1d: Risk of the Santa Catalina Island population reaching quasi-extinction using adult mortality rate and adult population size. Because the PVA model was not parameterized using data from Santa Catalina Island, this contour plot assumes that foxes on Santa Catalina Island have survival rates similar to foxes on Santa Cruz and San Miguel islands and reproductive rates similar to those on San Miguel Island. We assumed no rainfall effects on survival rates.***

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**Description of the model used to calculate the risk-based recovery criterion**

*This appendix is intended to briefly describe the methods and results of the updated island fox PVA upon which some of the recovery planning is based. The manuscript describing demographic analyses and population simulations making up the PVA is listed below*:

Bakker, V.J., D.F. Doak, G.W. Roemer, D.K. Garcelon, T.J. Coonan, S.A. Morrison, C. Lynch, K. Ralls, and M.R. Shaw. 2009. Incorporating ecological drivers and uncertainty into a demographic population viability analysis for the Island Fox (*Urocyon littoralis*). Ecological Monographs 79(1):77-108.Appendix 3: Technical Analysis Request 2.1 Development of Population Monitoring Plans for Free-Ranging Island Foxes

## C. APPENDIX 3: TECHNICAL ANALYSIS REQUEST 2.1 - DEVELOPMENT OF POPULATION MONITORING PLANS FOR FREE-RANGING ISLAND FOXES

The draft "Island Fox Strategy for Recovery" dated June 14, 2006, calls for long-term monitoring of all wild populations via the best established methods, to monitor population dynamics and to ensure that population declines are detected rapidly and their causes understood. A technical analysis is required to identify the specific objectives (i.e. parameters, precision) of such a monitoring program and to develop statistically robust methods to meet these objectives. The following outlines the goals of this analysis, suggests which Technical Expertise Groups should be included, and provides a generalized process by which a monitoring plan can be developed for each island:

1) The goals of this analyses are to:

   a) assess management objectives and needs related to the fox population on each island, and to recommend monitoring protocols designed specifically to address these management needs.

   b) recommend monitoring protocols to collect population parameters necessary for development and refinement of PVAs that may be used to guide management activities.

   c) recommend monitoring protocols to collect population parameters necessary to determine if recovery criteria, as adopted in the USFWS Recovery Plan, are reached.

   d) recommend monitoring protocols to collect population parameters necessary for cross-island comparisons to increase our knowledge about island fox population dynamics.

   e) recommend topics of future research modules which, although not part of a long-term monitoring plan, may be complementary to long-term monitoring activities.

   In addition, each monitoring plan should include recommendations that facilitate the collection of animal health measures necessary to track population health as per the recommendation of the Fox Health Technical Expertise Group.

2) Although the actual development of each island-specific monitoring plan is anticipated to be carried out by qualified contractors, the following Technical Expertise Groups ("TEG") should be involved in the conceptual development of monitoring plans and participate in a regular review of the plans as they are developed:

    a) Population Modeling

    b) Wild Population Management

    c) Fox Health

    A Task Force including the Chair of each of the above TEGs and/or their designated representatives should be available for discussion or review of issues as necessary. As work progresses, additional topics may be identified and included in plan development.

3) The following general steps and analyses should be included in developing each plan:

    a) Collect and review information pertinent to each island, including past and current monitoring programs, monitoring data, and ecological and physical characteristics of the islands as they relate to monitoring needs and constraints.

    b) Identify and articulate monitoring objectives using input from managers and the Task Force.

    c) Analyze existing protocols to evaluate whether they are generating the appropriate parameters needed to meet current monitoring objectives. For example, a representation analysis of current trapping protocols should be conducted to determine how well trapping efforts represent habitat variability (e.g. vegetation, topography, distance to shoreline, or general location on the island) and management issues (e.g. distance to roads) on the island.

    d) Develop recommended protocols, possibly with alternative scenarios, for

i) monitoring survival and cause specific survival

ii) sampling (trapping) to collect demographic data

e) Obtain input from managers and Task Force on the above protocols and alternative scenarios to determine feasibility and whether desired parameters will be generated.

f) Obtain input from a statistician on the above protocols and alternative scenarios to determine if methods are statistically robust.

g) Prepare draft and final monitoring plans for each island, allowing time for review and input from managers and Task Force.

This TAR relates to San Miguel, Santa Rosa, Santa Cruz, Santa Catalina, and San Nicolas Islands.

**The final Technical Analysis Request 2.1 can be found in:**

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 Integrated Recovery Team. 145pp + maps + app.

The complete monitoring framework can be accessed via the internet at:

http://www.fws.gov/ventura/

**Table 3-1 Monitoring goals for each island as stated and prioritized by island managers (from Rubin et al. 2007)**

| | Management goal: | Parameter needed: |
|---|---|---|
| **San Miguel** | 1. Monitor population status and trend.<br>2. Monitor threats to population (influences on population size and viability). | 1. Index of island-wide changes in abundance (annual change in island-wide N or density)<br>2a. Survival (by age, gender, year)<br>2b. Cause-specific mortality (predation, disease, etc.)<br>2c. Reproduction (annual recruitment) |
| **Santa Catalina** | **Management goal:**<br>1. Monitor threats to population (influences on population size and viability).<br>2. Monitor population status and trend.<br>3. Estimate population size | **Parameter needed:**<br>1a. Survival (by age, gender, year)<br>1b. Cause-specific mortality (predation, disease, etc.)<br>2. Index of island-wide changes in abundance (annual change in island-wide N or density)<br>3. Island-wide abundance estimate (N) |
| **Santa Rosa** | **Management goal:**<br>1. Monitor population status and trend.<br>2. Monitor threats to population (influences on population size and viability).<br>3. Inform land management decisions. | **Parameter needed:**<br>1. Index of island-wide changes in abundance (annual change in island-wide N or density)<br>2a. Survival (by age, gender, year)<br>2b. Cause-specific mortality (predation, disease, etc.)<br>2c. Reproduction (annual recruitment)<br>3. Density by habitat type |
| **Santa Cruz** | **Management goal:**<br>1. Monitor threats to population (influences on population size and viability).<br>2. Monitor population status and trend.<br>3. Inform land management decisions. | **Parameter needed:**<br>1a. Survival (by age, gender, year)<br>1b. Cause-specific mortality (predation, disease, etc.)<br>2. Index of island-wide changes in abundance (annual change in island-wide N or density)<br>3. Survival and density by habitat type |

## D. APPENDIX 4: GUIDELINES AND RECOMMENDATIONS ON VACCINATION PROTOCOLS, COLLECTION OF HEALTH DATA, AND FUTURE RESEARCH NEEDS RELATED TO FOX HEALTH.

This appendix includes additional details associated with Recovery Actions 1.2 to 1.4 of the Draft Recovery Plan for Four Subspecies of Island Fox and was developed in coordination with the Fox Health Technical Expertise Group.

**Recovery Action 1.2 – Avoid introduction of new pathogens, or novel strains of existing pathogens, to the Channel Islands by restricting or regulating movements of wild and domestic animals to the islands.**

Movement of both domestic and wild mammals to the northern Channel Islands is not permitted under Channel Islands National Park regulations, although a small number of domestic dogs have been brought to Santa Rosa and Santa Cruz Islands in association with the various forms of hunting operations. Additionally, there is a chronic risk of animals (particularly domestic dogs, cats, and rats) being brought ashore unofficially from boats.

Where there is a clear benefit to bringing such animals to the islands, veterinary experts familiar with threats to island foxes should be consulted to develop appropriate quarantine or containment protocols.

Restricting animal movements to Santa Catalina Island is more difficult than to the northern Channel Islands because Santa Catalina Island is composed entirely of private land, has thriving resident and visitor populations, and has easily accessible regularly scheduled transport to and from the mainland. Efforts to minimize animal movement to the island could include education campaigns, developing partnerships with the City of Avalon and others, and adopting regulations restricting such movement and controlling feral cats.

Education campaigns should be extended to mainland-based boaters that may inadvertently transport stowaway wildlife such as raccoons to the islands.

**Management and Removal of Introduced Mammals**

All islands should have protocols in place to deal with invasive animal introductions.

- Protocols should be communicated to non-fox personnel so that proper steps are taken in the event of discovery of invasive animals on boats or on an island.

- Parties involved with protocol development should be cognizant that return of wild animals to the mainland for release back into the wild may risk introduction of unique infectious agents (such as Spirocerca or island-evolved viral strains) to naïve mainland wildlife populations, and is not advisable.

- Protocols should address: 1) requiring return of a boat to the mainland before exit of a stowaway animal; 2) capture protocols developed with other agencies which might be involved (depending on the island) such as the California Department of Fish and Game (CDFG), the U.S. Navy, or the City of Avalon; 3) preconditions, indications, and protocols for lethal removal which should be developed with input from CDFG; 4) samples such as blood and feces which should be taken from captured invasive animals; 5) protocols for determining whether animals which have been lethally removed should be necropsied or otherwise tested for disease.

**Recovery Action 1.3 – Implement Prophylactic Management to avoid extinction or quasi-extinction of wild populations in the event of devastating epidemics.**

Any prophylactic vaccination against canine distemper virus (CDV) would need to take into account serological evidence that a strain of CDV is currently circulating within the wild populations on Santa Cruz and Santa Catalina Islands with no documented ill effects (strains with similarly benign effects occurred on San Miguel Island and Santa Rosa Island but may have been eliminated by vaccination when all foxes were taken into captivity and vaccinated). These strains may confer immunity to more dangerous strains; their eradication through vaccination should be avoided if possible. Maintaining a “core group” of a minimum of 80-100 CDV vaccinated individuals of each subspecies should allow such viruses to continue circulating in the unvaccinated proportion of each population. Larger numbers of animals may be vaccinated within “core” areas if managers wish to increase the likelihood of higher survival percentages in the event of a CDV epidemic.

Prophylactic vaccination against rabies should take into account the public health concerns that are associated with rabies, the risks to personnel incurred when handling potentially infected foxes for the purpose of vaccination in the event of an epidemic, and the potential desire of managers to increase the likelihood of survival percentages that are greater than the minimums required to avoid quasi-extinction. Maintaining a core group of a minimum of 80 – 100 individuals vaccinated against rabies, plus as many additional individuals in the population as can be opportunistically vaccinated, is advisable in order to maximize the number of foxes that would be expected to survive an epidemic. This approach would also reduce the level of threat to human and domestic animal populations that are in contact with island foxes.

**1.3.1 – Test safety and antibody response to vaccination in captive island foxes under appropriate research protocols.**

**1.3.1.1 -** Conduct CDV vaccination trials by administering two vaccinations at different bodily locations on island foxes during a single vaccination event**.**

Purevax™ recombinant CDV vaccine has been shown to be safe for use in island foxes, and to trigger seroconversion after administration of two intramuscular doses of vaccine given two weeks apart. However, field application of the vaccine would be more practicable if protection could reliably be achieved in the course of a single handling event, recently done successfully with wild dogs.

**1.3.1.2 -** Assess the efficacy of standard inactivated rabies vaccines in producing an antibody response in island foxes

This may be achievable using serum already banked from captive island foxes. Further studies are likely to be necessary if initial investigations suggest a poor immune response to rabies vaccination as implemented. Recombinant subunit rabies vaccines also need to be tested for safety and ability to induce an antibody response. Additionally, rabies vaccine delivered in bait should be assessed for ability to induce an antibody response.

**1.3.1.3 –** Vaccines against canine parvovirus and adenovirus should be tested on island foxes

Inactivated and monovalent modified live vaccines should be considered for testing with the knowledge that inactivated vaccines may not induce a robust antibody response and modified-live vaccines may induce disease. While an epidemic of parvovirus or adenovirus is unlikely to occur in the near future because of evidence of extensive exposure in the current populations, testing vaccines would be appropriate to have knowledge of their safety and effects if future vaccination is needed.

**1.3.2 –** On each island, maintain vaccination cover for rabies and CDV in at least 80 to 100 island foxes

All vaccinated foxes should be permanently marked, and detailed records should be maintained on the vaccination status of all island foxes handled, whether in the wild or in captivity. This is important to avoid confusion in the future interpretation of serology results.

Given uncertainties about the immune status of island foxes given single vs. repeated doses of vaccine, and the desirability of retaining nonlethal CDV strains in circulation on the islands if possible, it would be advisable to identify (and mark) the individuals to be vaccinated, and then re-vaccinate as many as possible. Because of attrition and failure to capture vaccinated individuals, new individuals may need to be vaccinated annually to maintain a core population of vaccinated island foxes. Less systematic approaches risk protecting too few island foxes (if single doses of vaccine do not confer protection, and only a proportion can be recaptured for boosters), or too many island foxes (if single doses are effective but assumed not to be so).

**Recovery Action 1.4 – Establish monitoring and response strategies to detect and manage infectious disease threats to island fox population persistence.**

**1.4.1 – Monitor to detect disease-related mortality**

Ensure that management activities to avoid introducing new infectious diseases to island fox populations, and to avoid complete extinction in the face of devastating epidemics, are combined with mechanisms to detect, and respond to, any outbreaks that could occur.

All staff working on the Channel Islands, irrespective of their duties and expertise, should be trained to recognize and immediately report sick or dead carnivores, including island foxes. All staff should be trained to avoid exposure to diseases.

Necropsies should be performed as soon as possible for all carnivores that die from causes other than trauma to determine if the cause was an infectious disease potentially transmissible to island foxes.

**1.4.2 – Annually collect blood samples from a proportion of island foxes on all islands to evaluate ongoing disease risks to island fox populations**

Decisions about whether or not clinical interventions are justified will depend not only on information on mortality but also on the immune status of the population concerned. For example, a recent study suggests evidence that foxes on all islands have been exposed to CDV and canine parvovirus (Clifford et al. 2006), indicating some degree of population protection and therefore little need to intervene if a small number of deaths were detected. However, patterns of exposure are likely to be dynamic and in small isolated populations pathogen populations can easily die out leaving the host population entirely susceptible to reinfection a generation later.

Island fox blood samples should be collected from a representative proportion of each subspecies during each year. If achievable, these samples should be collected, at a minimum, from each island fox population during each year including:

- all radio-collared individuals;
- 25 individuals sampled in a previous year;
- up to 25 previously un-sampled adults from a variety of age classes and geographical location; and
- as many previously unsampled yearlings and pups (aged >5 months to avoid maternal antibodies) as possible.

**1.4.3 – Develop response strategies for responding to island fox deaths from infectious diseases known to represent serious threats to the persistence or recovery of the wild populations.**

This strategy should include:

- a list of the veterinarians and other relevant experts willing and able to advise on appropriate management, and their emergency contact details;
- a protocol for expediting transportation of relevant personnel to the affected island(s);
- facilities, equipment and supplies on site for investigating an outbreak;
- facilities, equipment and supplies on site for vaccination, quarantine, or treatment if indicated;
- measures to contact and work with these individuals if a disease outbreak occurs; and
- a stockpile of traps to capture island foxes if needed for vaccination.

**Intervention for rabies**

Intervention in a rabies epidemic may or may not be advisable, and is dependent on many factors. These include the percentage of the population that had been previously vaccinated, the geographic extent of detected disease, the availability of oral bait-based vaccine, and the number of personnel available to implement an intervention strategy who are vaccinated against rabies and properly trained. Immediate vaccination of all wild island foxes on the affected island, preferably commencing in areas remote from the index case, is advisable if oral bait-based vaccines are available, and have been tested and shown to be safe for island foxes. Trapping and vaccinating could pose unacceptable risks to personnel, and should not be utilized unless absolutely necessary, and only after consultation with the island fox health expertise group and other experts. The intensity of monitoring should be increased island-wide to detect both sick and dead animals. Euthanasia is recommended for sick animals. Rabies vaccination of human staff on the Channel Islands would also be advisable under these circumstances. Regular training should be conducted to minimize the likelihood of inadvertent human exposure to rabies in the event of an epidemic.

**Intervention for canine distemper**

Intervention in a CDV epidemic may or may not be advisable, and is dependent on many factors. These include the percentage of the population that had been previously vaccinated, the geographic extent of detected disease, the availability of adequate isolation, and levels of staff training. Intervention could include immediate vaccination of all wild island foxes on the affected island, preferably commencing in areas remote from the index case, however trapping and vaccinating could potentially increase the spread of the disease via contaminated equipment or personnel. The intensity of monitoring should be increased island-wide to detect both sick and dead animals. Euthanasia of sick animals may be advisable after veterinary exam or consultation if isolation from other island foxes, both in the wild and in captivity, cannot be assured. Bringing apparently healthy foxes into captivity may also be inadvisable unless strict individual quarantine measures are possible, since some apparently healthy individuals could be incubating the disease. Screening of accumulated serum samples should be commenced immediately. Further blood sampling of the wild island fox population could be used to track the epidemic; serum from juveniles (aged 5-12 months) would be particularly helpful in this regard. Maintain a stockpile of Merial Purevax Ferret™ vaccine sufficient to protect a population in the face of a CDV outbreak at a central location and used as needed on whichever of the islands may be affected. Merial Purevax Ferret™ is the only vaccine against CDV that is both safe for use in island foxes and also triggers seroconversion; however, it is only available intermittently.

**Intervention for parvovirus or adenovirus**

Sick island foxes may be taken into captivity, isolated, and treated if proper isolation facilities and trained personnel are available. Scat surveys should be conducted to evaluate the prevalence of virus-induced diarrhea. If the virus were to be isolated from any sample, the strain should be investigated. As for CDV, screening of accumulated serum samples should be commenced immediately, as should prospective sampling to track the progression of the epidemic. Samples from juveniles (aged 5-12 months) would be particularly valuable for the latter purpose.

## Literature Cited

Clifford, D.L., J.A.K. Mazet, E.J. Dubovi, D.K. Garcelon, T.J. Coonan, P.J. Conrad, and L. Munson. 2006. Pathogen exposure in endangered island fox (*Urocyon littoralis*) populations: implications for conservation management. Biological Conservation 131:230-243.

## E. APPENDIX 5: QUARANTINE GUIDELINES FOR BRINGING DOGS FROM THE MAINLAND TO THE NORTHERN CHANNEL ISLANDS

**Entry Requirements for dogs originating from U.S.A.**

### Pre-Movement Quarantine

All dogs destined for shipment must be placed in a quarantine facility for 30 days before transport to the northern Channel Islands. The purpose of this quarantine facility is to prevent infection of the dogs after they have been tested and treated for parasites and infectious diseases. The facility should be: 1) isolated from contact with other carnivores, and 2) an all-in/all-out facility (no entry of new animals during the 30 days). If possible, the dogs should be individually housed and the substrate should be concrete or other surface that can be disinfected.

### Vaccination

All dogs will have a current vaccination for the following:

DHPP (LC) - Modified Live Virus Vaccines

- Canine distemper virus
- Canine infectious hepatitis (canine adenovirus)
- Canine parainfluenza virus
- Canine parvovirus
- Leptospirosis
- Coronavirus

Killed Vaccines

- Rabies
- *Bordetella* (kennel cough)

The entire vaccination series will be completed at least one month, but no more than six months, prior to the dog's arrival on any of the northern Channel Islands. Dogs vaccinated less than one month prior to transport may shed modified vaccine virus or viruses acquired through natural exposure before being protected by vaccines.

Evidence of vaccination must be provided to TNC and/or NPS, as applicable, two weeks prior to the dog traveling to the northern Channel Islands.

Dogs remaining on any of the northern Channel Islands must be vaccinated annually and kept in quarantine for 30 days after vaccination.

**Parasites**

All dogs must be negative for heartworms (*Dirofilaria immitis*) by DiroCheck® or SNAP® tests and be screened for microfiliaria six months before being transported to any of the northern Channel Islands. Dogs must then be placed on an appropriate heartworm preventative and kept on preventative treatments while on-island. Recommended preventative treatments are Heartgard Plus® or Interceptor®.

All dogs must test negative for endoparasites prior to transport to any of the northern Channel Islands. Three consecutive fecal samples must be tested for endoparasites using both zinc and sugar floatation methods. Dogs with positive fecal tests should be treated with appropriate anthelmintics and then re-tested until they have three consecutive fecal samples test negative. If dogs are not individually housed, then all contact animals must also be treated and retested. Dogs should be rechecked by the same protocol annually.

During quarantine, all dogs must be checked for ectoparasites, including *Sarcoptes, Demodex* and *Otodectes* mites. If positive for any mite, the dogs should be appropriately treated and rechecked until negative. If dogs are not individually housed, all contact animals should also be treated and retested. Once negative for ectoparasites, the dogs should be placed on an appropriate preventative before being transported to any of the northern Channel Islands. Recommended preventative treatments are Interceptor® or Frontline®.

**Health Certificate**

All dogs must be given a complete physical exam by a licenced veterinarian to confirm that they are in good general health and free of evidence of any infectious diseases within ten days of being transported to any of the northern Channel Islands. The examination should include confirmation of vaccination status, confirmation of negative heartworm, endoparasite, and ectoparasite tests (including ear mites) and a negative Lyme disease test.

**Post-transport Quarantine on the northern Channel Islands**

Vaccinated animals can still be subclinically infected with infectious agents, such as canine distemper, and can therefore act as a source of infection for island foxes. Most dogs that mount an effective immune response to canine distemper virus clear the virus from their system within two weeks of exposure and cease to shed the virus. Also, most subclinical diseases caused by other agents usually become apparent within three weeks. Therefore all dogs transported to the islands must be quarantined on-island for three weeks in a location and facility that is inaccessible to island foxes. Feces and urine from quarantined dogs should be disposed of in such a manner that foxes are not exposed to either feces or urine or the effluent from the disposal areas.

**Inter-Island Travel and Re-entry Requirements**

The requirements for vaccination, parasite screening and quarantine are triggered each time a dog travels from the mainland to an island or travels between islands.

## F. APPENDIX 6: GUIDELINES FOR ESTABLISHING A MAINLAND POPULATION OF ISLAND FOXES WITH TASKS, RESPONSIBLE PARTIES, AND TIME FRAMES

This table of identified steps was modified from May 2005 Technical Analysis Response 3.6.

| Task | Actions | Responsible Parties |
|---|---|---|
| Obtain necessary ESA permits and authorizations | | |
| | Establish an ESA and CDFG permit held by the FWS for all mainland activities, including quarantine, holding, breeding, research and animal shipments | FWS, CDFG |
| | Develop boiler-plate captive holding agreement from CDFG to each mainland holding facility providing authorization and guidance on ESA activities | AZA-SSP, FWS, CDFG |
| Develop necessary shipping, quarantine, and holding protocols and guidelines | | |
| | Develop a standardized animal shipment protocol for off island transfers | AZA-SSP |
| | Develop mainland facility approval and review policies and procedures. | AZA-SSP , FWS, CDFG |
| | Develop draft quarantine protocols | Completed |
| | Submit draft quarantine protocols to Health TEG for review | Completed |
| | Finalize Quarantine protocol | Randy Junge for Health TEG |
| | Present Quarantine protocol to Group | Health TEG |
| | Create standardized protocols for preventive medicine while on mainland | Health TEG |
| Develop AZA Species Survival Plan (SSP) to provide oversight of mainland population | | |
| | Establish an MOU between AZA and the FWS | Completed |
| | Establish an AZA Island Fox SSP | AZA Canid TAG |
| | Name a SSP Coordinator, Studbook Keeper and necessary Advisor(s) | AZA Canid TAG |
| | Recognition by the FWS and CDFG of the AZA Island Fox SSP as the knowledgeable authority on mainland captive breeding for Island foxes | FWS, CDFG |
| | Decide SSP goals for mainland population | AZA-SSP, TAG, FWS, NPS, TNC, CDFG |
| | Recruit SSP institutions | AZA-SSP |
| | Develop SSP Master Plan | AZA-SSP |

| Task | Actions | Responsible Parties |
|---|---|---|
| Address financial oversight issues and concerns | | |
| | Set up a FWS and CDFG grant agreement with SSP | FWS, CDFG |
| | Each holding institution takes financial responsibility for animals held | AZA-SSP, Each holding facility |
| | Liaise with Friends of the Island Fox, Inc. (FIFI) for development activities | AZA-SSP, FIFI, FWS |
| | ID private sources of funding | AZA-SSP, FIFI |
| | ID grant sources of funding | AZA-SSP, FIFI |
| | Set up gifted endowment | FIFI |

## G. APPENDIX 7: IDENTIFIED RESEARCH NEEDS USING A MAINLAND CAPTIVE ISLAND FOX POPULATION

15 July 2007

**A. Ensure that husbandry and management practices in captive facilities enhance animal welfare and maximize breeding success.**

- Develop methodologies to encourage maximum breeding success, together with methods for monitoring and record keeping.
- Determine the "Best Management Practices" for housing, managing and breeding captive Island foxes through testing of different housing and management protocols. Analyze research results on the social and reproductive behavior of wild island foxes to inform captive husbandry and management.
- Using an adaptive management paradigm, ensure that captive facilities conform to the best animal care standards known for comparable species and facilities. Strive to achieve captive breeding success rates for island foxes that are comparable with the most successful canid breeding program in the AZA's Canid Taxon Advisory Group (TAG).

B. **Conduct research using captive island fox populations to enhance their welfare and breeding success in captivity, and to help identify, eliminate and control threats to the recovery and sustainability of wild island fox populations.**

- Analyze mechanisms of mate choice and mate compatibility, e.g. determine the differences in behavioral characteristics of successful and unsuccessful mated pairs and the underlying cause(s).
- Analyze husbandry and management factors contributing to reproductive success and failure, e.g. determine when in the reproductive cycle failure occurs; determine factors contributing to pup loss; determine the best pen design and management practices for captive island foxes; determine the best management practices for facilitating successful mate choice and producing successful breeding pairs.

- Conduct biomedical research on captive populations to help eliminate and/or control disease threats to the wild and captive island fox populations, e.g. develop and test vaccines using captive individuals to help develop protocols and practices for vaccinations of wild island foxes.

- Conduct and perfect semen collection, cryo-preservation and semen banking for a genetic bank.

C. **Develop "Best Management Practices" for rearing island foxes for release into the wild and for their reintroduction.**

- Identify and conduct research on the management and husbandry factors that influence post-release survival of island foxes.

- Develop the most cost-effective methods of housing and rearing island foxes to preserve their ability to survive in the wild. Develop objectives for evaluation of success of management protocols.

- Develop "Best Management Practices" for releasing island foxes into the wild and for post-release management and monitoring. Variables that need consideration include, in priority order, feeding regimes before and after release, post-release support (e.g. food supplementation and shelter), individual differences in island fox behavior, pre-release housing and adaptation to release sites, social groupings, and medical exams. Include for each variable how, what, how much, when, and for how long.

  1. Develop standardized protocols for pre-release preparation.

  2. Develop objectives for evaluation of reintroduction success.

  3. Develop and implement standardized techniques for post-release management and monitoring. Ensure compatibility between short-term monitoring of new releases and long-term monitoring protocols for the wild island fox populations.

## H. APPENDIX 8: LIST OF TECHNICAL ANALYSIS REQUESTS (TARS)

Copies of these technical reports can be obtained by contacting the Ventura Fish and Wildlife Office at 805-644-1766 or 2493 Portola Road, Suite B; Ventura, California 93003.

Note that some of the information and/or recommendations provided in these analyses may no longer be up-to-date or consistent with current island fox recovery efforts. Some approaches to recovery have changed since they were developed and may change in the future as new information arises.

**Technical Analysis 1.3**

Use the PVA models and supporting data to determine the conditions in the wild populations that would trigger taking further foxes into captivity (e.g., during pig eradication on Santa Cruz, or if another disease outbreak occurred).

**Technical Analysis 2.1**

Development of population monitoring plans for free-ranging island foxes.

**Technical Analysis 3.1**

Determine the target captive population size for each subspecies, building on population viability analyses for wild population and demographic and genetic data on which these models are based.

**Urgent Technical Analysis Related to Analyses 3.1 and 3.3**

Determine whether, how, and where to release captive-bred foxes this fall and, if no releases, develop contingency plans that may include establishing mainland populations or expanding existing on-island populations.

**Technical Analysis 3.4**

Develop management and husbandry plans for each subspecies, taking into account studbook data, and results from research into best husbandry practices (pen size, social structure, mate choice, etc). The focus for research and management for each captive population will depend on the size and stability of that subspecies' wild and captive populations.

**Technical Analysis 3.6**

Assessment of the potential benefits and costs of long-term captive populations on the mainland and/or islands.

**Sub-Analysis 3.6.1:**

Identity and describe the potential benefits, costs, and major issues associated with the following strategies (or combinations of thereof) for maintaining captive populations of island foxes:

a. using existing on-island facilities.
b. expanding on-island facilities.
c. using existing space in mainland facilities (e.g., zoos).
d. constructing new mainland facilities for island foxes.

**Sub-Analysis 3.6.2:**

Identify to the extent possible the necessary steps and their logical progression for establishing and managing captive populations on the mainland.

**Sub-Analysis 3.6.3:**

If the establishment of mainland populations is determined to be both desirable and practical, identify weight criteria to be used to prioritize subspecies of the island foxes for representation in mainland populations.

**Technical Analysis 4.1**

Analyze efficacy of golden eagle control and capture methods utilized to date and recommend innovative program for removal methods, taking into account the most up-to-date information on the status of the wild fox populations.

**Table 8-1: Date that the Island Fox Recovery Coordination Group (RCG) issued their recommendation for each TAR.**

| | |
|---|---|
| TAR 1.3 | September 10, 2004 |
| TAR 2.1 | The RCG did not issue a recommendation associated with this TAR. The request was sent October 20, 2006. |
| TAR 3.1 | See "Urgent Technical Analysis Related to Analyses 3.1 and 3.3." |
| Urgent Technical Analysis Related to Analyses 3.1 and 3.3 | October 4, 2004 |
| TAR 3.4 | April 12, 2005 |
| TAR 3.6 | February 9, 2006 |
| TAR 4.1 | January 7, 2004 |

# I. APPENDIX 9: GLOSSARY OF TERMS IN THE RECOVERY PLAN FOR FOUR SUBSPECIES OF ISLAND FOX

**Age class** Foxes are aged according to tooth eruption and wear patterns on the first upper molar (Wood 1958; Roemer 1999) and are assigned to discrete age classes: pups (Age Class 0), young adults (Age Class 1: 7 months to 2 years), adults (Age Class 2: 2 to 3 years), mature adults (Age Class 3: 3 to 4 years) and old adults (Age Class 4: greater than 4 years) (Roemer 1999).

**Allee effects** Allee effects occur when population growth rate decreases with declining density. Allee effects are expected to occur at very small population sizes and may arise due to mate scarcity, inbreeding, or disruption in social behavior.

**Allele** An allele is one member of a pair or series of genes that occupy a specific position on a specific chromosome.

**Allelic diversity** Allelic diversity is the average number of alleles per locus.

**Allozyme** Allozymes are variable forms of the same enzyme. They differ because they originate from different genetic sequences. Studying allozyme variation in a population is an indirect measure of the genetic variation of the population. In this type of study, whole proteins are analyzed instead of the genes they originated from. If there is no genetic variation in a population (monomorphic = "one form"), the entire population uses just one form of the gene. If the population shows polymorphisms ("many forms") of allozymes, this can be used to describe how much variation is present.

| | |
|---|---|
| **Anthelmintics** | Anthelmintics are agents used to treat parasitic worms in animals. |
| **Bottleneck** | A population undergoes a bottleneck when a combination of environmental conditions occurs that causes a serious reduction in the size of a population. A population that has undergone a bottleneck often has reduced genetic diversity. |
| **Caliciviruses** | Members of the Caliciviridae family of viruses. Calicivirus infections commonly cause acute gastroenteritis, which is the inflammation of the stomach and intestines. Symptoms can include vomiting and diarrhea. |
| **Contraindication** | A contraindication is a specific situation in which a drug, procedure, or surgery should not be used, because it may be harmful to the patient. |
| **Demographic** | A characteristic used to describe some measurable aspect of a population, such as growth rate, age structure, birth rate, and gross reproduction rate. |
| **Diurnal** | An animal that is diurnal is active during the daytime and rests during the night, as opposed to an animal that is nocturnal, or mostly active during the nighttime. |
| **DNA restriction fragments** | A DNA restriction fragment is a DNA fragment resulting from the cutting of a DNA strand by a restriction enzyme by a process called restriction. Each restriction enzyme is highly specific, recognizing a particular short DNA sequence and cutting both DNA strands at specific points within this site. Restriction fragments can be analyzed using techniques such as gel electrophoresis or used in recombinant DNA technology. |

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| **Docile canid** | A docile canid refers to any of the various widely distributed carnivorous or omnivorous mammals of the family Canidae, which includes the foxes, wolves, dogs, jackals, and coyotes, that are easily managed or handled. |
| **Endoparasite** | An endoparasite is a parasite that inhabits the internal organs or tissues of an animal or plant |
| **Effective population size** | The effective population size refers to the average number of individuals in a population that actually contribute genes to succeeding generations by breeding. This number is generally lower than the observed population size. |
| **Founder** | A founder is an individual that established a population. The founders referred to in this draft recovery plan are the individuals that were captured from the wild and brought into captivity, establishing the captive breeding programs. |
| **Hacking** | Hacking is a technique used in the captive release of birds of prey where shelter and food is provided for a bird prior to fledging and is continued to be provided until the fledging becomes independent. |
| **Heterozygosity** | Heterozygosity is the proportion of individuals heterozygous at all loci divided by the number of loci. |
| **Heterozygous** | Heterozygous refers to an individual that possesses two different forms of a particular gene, one inherited from each parent. |
| **Hyperpredation** | Analogous to apparent competition (Holt 1977), hyperpredation occurs when a prey species that can sustain high predation rates subsidizes the extinction of another prey species by acting as an |

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|---|---|
| | alternate food resource for a shared predator (Courchamp et al. 1999). |
| **Hypervariable DNA** | Usually used to describe the sequences of DNA that do not have a function in the organism, a.k.a. "junk" DNA. These sequences are especially useful for determining differences within the population, because these regions of DNA are not critical and can vary greatly from one individual to another with no consequence. |
| **Inbreeding depression** | Inbreeding depression is an increased expression of deleterious alleles in individuals, resulting in an overall decline in the vigor of a population, due to mating among relatives. |
| **Intraspecific aggression** | Intraspecific aggression refers to aggression among members of a single species. |
| **Isocline** | An isocline is aseries of lines with the same slope. For our purposes, an isocline graph provides a way to visually identify where an island fox population stands in regards to current on-island parameters. |
| **Loci (plural of locus)** | In genetics, the locus is a specific place on a chromosome where a gene is located. |
| **Major Histocompatibility Complex (MHC)** | Genetic loci that encode for three classes of transmembrane (cell) proteins. These proteins induce the organism's immune response. This region is especially important in genetic studies since these types of genes are found in all vertebrates and are numerous, making these regions a rich source of information regarding genetic evolutionary lineage. There can be hundreds of alleles of each MHC locus. |
| **Metastasize** | The spreading of cancer cells from their original site to other parts of the body. |

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|---|---|
| **Microsatellite DNA** | Pieces of the same small DNA sequence which are repeated, often in non-coding genetic regions of the chromosome ("junk" DNA that does not contain any genes).<br><br>For example, if a small nucleotide sequence normally repeats within a species' genome, it may repeat a different number of times in different individuals. The number of repeats is easily detected and serves as a basis for measuring the genetic variability within the population. |
| **Minisatellite DNA** | Similar to microsatellite DNA, minisatellites are longer DNA sequences (1000 to 5000 bases long) of 20-50 repeats. |
| **Mitochondrial DNA** | The DNA within an organism's cells that is located inside the mitochondria, not inside the nucleus. Mitochondrial DNA is maternally inherited in most species and is used widely to assess taxonomic relationships and differences among populations and species. Mitochondrial DNA analysis (mtDNA) can be used to examine older biological samples that lack cellular material with a nucleus (nucleated), such as hair, bones, and teeth. |
| **Morbillivirus** | Morbillivirus is a genus of viruses in the family of Paramyxoviridae that includes the causative agents of measles, canine distemper virus, phocine distemper, and rinderpest. |
| **Necropsy** | A necropsy is an examination and dissection of a dead body to determine cause of death or the changes produced by disease. |
| **Oocyst** | An oocyst is the thick-walled spore phase of certain protists (sporozoans), such as Cryptosporidium and Toxoplasma. |

| | |
|---|---|
| **Otitis** | Otitis is a bacterial infection of the ear. |
| **Pelage** | Pelage is the wool, fur, or hair coat of a mammal. |
| **Phylogeny** | Phylogeny is the evolutionary development and history of a species or higher taxonomic grouping of organisms. |
| **Polymorphism** | Polymorphism is the existence of two or more forms of individuals within the same animal species (independent of sex differences). |
| **Prophylactic management** | Implementation of protective measures to prevent disease or extinction. |
| **Quasi-extinction** | Quasi-extinction is a drop in numbers of individuals to some very low level at which the population is expected to be critically imperiled. At quasi-extinction, population dynamics are expected to be immediately and adversely affected by factors such as Allee effects, inbreeding depression, and demographic randomness. At this point, management options are severely constrained. |
| **Serological** | A serological test or survey pertains to the measurement and characterization of antibodies, antigens, and other immunological substances in body fluids (serum), usually blood. |
| **Stochastic events** | Chance or random events. |
| **Sympatric** | Sympatric refers to populations or closely related species that occupy the same or overlapping geographic areas without interbreeding. |
| **Synergistic** | Different actions combined or correlated, working together. |

**Toxoplasmosis** An intracellular tissue infection of a parasite from the genus *Toxoplasma*, particularly in mammals and birds.

**Vital rates** Rates of those components; such as birth, marriage, fertility, and death; which indicate the nature and possible changes in a population. Even when population numbers are stable, there may be changes in the vital rates.

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## J. APPENDIX 10: ACRONYMS AND ABBREVIATIONS IN THE DRAFT RECOVERY PLAN FOR FOUR SUBSPECIES OF ISLAND FOX

| | |
|---|---|
| AZA | Association of Zoos and Aquariums |
| CBI | Conservation Biology Institute |
| CDFG | California Department of Fish and Game |
| CDV | Canine distemper virus |
| CIC | Santa Catalina Island Conservancy |
| CINP | Channel Islands National Park |
| DDT | Dichlorodiphenyltrichloroethane |
| DNA | Deoxyribonucleic acid |
| ENSO | El Niño Southern Oscillations |
| ESA | Endangered Species Act of 1973, as amended |
| FIV | Feline immunodeficiency virus |
| FeLV | Feline leukemia virus |
| FWS | U.S. Fish and Wildlife Service |
| GIS | Geographic Information System |
| IRT | Island Fox Integrated Recovery Team |
| IUCN | World Conservation Union (formerly called International Union for Conservation of Nature and Natural Resources) |
| IA | Interagency Agreement |
| IWS | Institute for Wildlife Studies |
| $Km^2$ | Square kilometer |

| | |
|---|---|
| MHC | Major Histocompatibility Complex |
| MOA | Memorandum of Agreement |
| NEPA | National Environmental Policy Act |
| NPS | National Park Service |
| PMTC | Pacific Missile Test Center |
| PVA | Population Viability Analysis |
| RCG | Island Fox Recovery Coordination Group |
| SSC | Species Survival Commission |
| SSP | Species Survival Plan |
| TAG | Taxon Advisory Group |
| TAR | Technical Analysis Request |
| TBD | To be determined |
| TEG | Technical Expertise Group |
| TNC | The Nature Conservancy |
| USGS-BRD | U.S. Geological Survey - Biological Resource Discipline |
| UNIV | University or academic researchers |

**U.S. Fish & Wildlife Service**
**Pacific Southwest Region**
**Sacramento, CA**

**http://www.fws.gov/cno**

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