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ON THE FAST TRACK TO RECOVERY: ISLAND FOXES ON THE NORTHERN CHANNEL ISLANDS

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ABSTRACT.—The island fox (*Urocyon littoralis*) represents an unusual case of a species that achieved virtual recovery a mere 15 years after population declines were first discovered. Island fox subspecies on San Miguel, Santa Rosa, and Santa Cruz islands declined precipitously in the mid-1990s due to predation by Golden Eagles (*Aquila chrysaetos*), which had not historically bred on the islands. In 2008, a 10-year period of recovery action implementation ended. The recovery program had included captive breeding and reintroduction of island foxes and capture and relocation of Golden Eagles. Free-ranging fox populations have been monitored to assess recovery of each subspecies and to detect potential threats of disease and predation. Monitoring included (1) annual grid trapping to allow estimation of annual population size via capture-mark-recapture methods and (2) systematic surveillance of radio-collared foxes to allow estimation of mortality rates and causes. A comprehensive demographic modeling effort produced a population recovery tool that uses adult mortality and population size estimates from the monitoring programs to estimate extinction risks for each fox population. The tool allows managers to assess when threats are sufficiently mitigated to consider populations acceptably safe from extinction. Population monitoring indicates that island foxes on the northern Channel Islands have increased up to 30-fold from population lows and that annual survival has been 90% or better in most years. The San Miguel and Santa Cruz subspecies have approached or reached predecline population levels, and application of the recovery tool indicates they will be biologically recovered by 2013. Biological recovery of the Santa Rosa subspecies, hindered by predation which caused lower survival in 2010, will occur by 2017.

RESUMEN.—El zorro (*Urocyon littoralis*) representa un caso inusual de una especie que consiguió recuperarse virtualmente en sólo 15 años después de que el declive de sus poblaciones fuera descubierto por primera vez. Subespecies del zorro en las islas San Miguel, Santa Rosa y Santa Cruz disminuyeron estrepitosamente a mediados de los años 90 debido a la depredación de las águilas doradas (*Aquila chrysaetos*), que no se habían criado históricamente en las islas. Un período de 10 años de implementación de la acción de recuperación terminó en 2008, e incluyó la cría en cautiverio y la reintroducción de zorros, y la captura y reubicación de las águilas doradas. Se han monitoreado poblaciones de zorros en libertad para evaluar la recuperación de cada subespecie y para detectar posibles amenazas de enfermedades y depredación. El monitoreo incluyó (1) el trampeo anual por coordenadas para estimar el tamaño de la población anual con métodos de captura-marcaje-recaptura; y (2) vigilancia sistemática de zorros con collares de rastreo para calcular los niveles de mortalidad y sus causas. Un exhaustivo modelo demográfico produjo una "herramienta de recuperación de la población" que calcula el riesgo de extinción de cada población de zorros, utilizando las estimaciones de los monitoreos de la mortalidad adulta y el tamaño de la población. La herramienta permite evaluar cuándo las amenazas son lo suficientemente debilitadas como para considerar que las poblaciones están a salvo de la extinción. El monitoreo de la población indica que los zorros de las Islas del Canal del norte han aumentado hasta 30 veces el número mínimo de la población y que la supervivencia anual ha sido del 90% o superior en la mayoría de los años. Las subespecies de San Miguel y Santa Cruz se han acercado o han llegado a niveles de población pre-declive y la aplicación de la herramienta de recuperación indica que se habrán recuperado biológicamente para el año 2013. La recuperación biológica de las subespecies de Santa Rosa, dificultada por el bajo nivel de supervivencia provocado por la depredación en 2010, ocurrirá en el 2017.

The recovery of a federally listed endangered species poses many challenges, among them the implementation of effective and timely recovery actions and the determination of when biological recovery has been achieved so that actions can be curtailed. The island fox (*Urocyon littoralis*) is endemic to the 6 largest of the 8 Channel Islands in southern California (USA) (Fig. 1) and occurs naturally at small population sizes that range from <500 to 2000 adults (Roemer et al 1994). In 2004, four subspecies of island fox were federally

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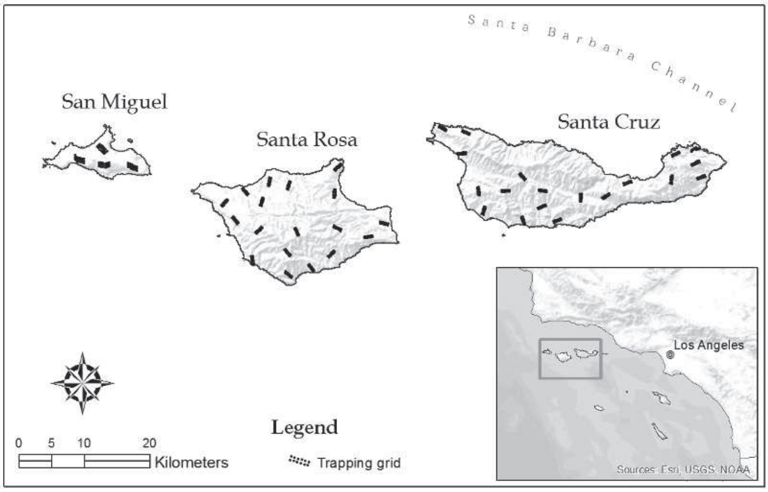

Fig. 1. Locations of grids for monitoring island foxes on San Miguel Island, Santa Rosa Island, and Santa Cruz Island, California.

listed as endangered (USFWS 2004), 5 years after those populations had reached a nadir due to predation in 3 cases and epidemic disease in another (Coonan et al. 2010). Beginning in 1999, well ahead of formal recovery planning efforts, managers on the northern Channel Islands (home to 3 of the 4 listed subspecies) initiated a range of management interventions to halt and reverse fox population declines. These interventions included relocation of a predator, the Golden Eagle (*Aquila chrysaetos*); captive breeding; vaccination to reduce risk of disease; and intensive demographic monitoring. Informal cooperation, planning, and actions undertaken by island managers and scientists were bolstered in 2004 by the formation of an Integrated Island Fox Recovery Team, which undertook the task of drafting a formal recovery plan.

Comprehensive recovery actions were quickly implemented and immediately effective (Coonan et al. 2010). To protect remaining foxes from eagle predation and to initiate a captive breeding program, all remaining foxes on San Miguel and Santa Rosa Islands were brought into captivity in 1999–2000, and 20 foxes from Santa Cruz Island were brought into captivity in 2002. Rapid growth of captive breeding populations allowed captive releases to begin in 2003, and they were completed by 2008. Golden Eagle relocation commenced on the islands in 1999 and reduced both mortality of foxes and the number of resident eagles on the islands (Coonan et al. 2010). The last nesting eagle was removed in 2006, and predation impact is currently limited to that of an occasional transient eagle. Concurrently, feral pigs were removed from Santa Cruz Island in 2005–2006 (Morrison et al. 2007), and all but a few nonnative ungulates were removed from Santa Rosa Island by 2013. The latter ecosystem-level recovery actions were necessary to remove nonnative prey that had supported breeding Golden Eagle populations on the islands (Roemer et al. 2001, Collins and Latta 2009).

Here, we report on the status of island fox recovery on the northern Channel Islands, driven by these conservation measures. We assessed recovery status by monitoring population size and survival and by using a recovery tracking tool to assess attainment of biological recovery for listed island fox subspecies. We confine our analysis to the 3 listed subspecies that occur on the northern Channel Islands: San Miguel Island fox (*U. l. littoralis*), Santa Rosa Island fox (*U. l. santarosae*), and Santa Cruz Island fox (*U. l. santacruzae*). Recovery of the Santa Catalina Island fox (*U. l. catalinae*) is covered elsewhere in this volume (King et al. 2014).

METHODS

San Miguel, Santa Rosa, and Santa Cruz islands are nearshore islands located 35–50 km from mainland California. San Miguel (38 km^2) is the smallest island on which island foxes occur, whereas Santa Cruz (243 km^2) and Santa Rosa (216 km^2) are 2 of the largest. All 3 islands are recovering from a history of grazing. San Miguel has relatively gentle topography and is dominated by grasslands and shrub communities, such as coastal sage scrub. The 2 larger islands have higher elevations, more topographic diversity, and additional vegetation associations, including chaparral, oak woodlands, and pine forests.

Population Monitoring

Annual estimates of adult (nonpup) population size were derived from capture-mark-recapture data. Foxes were trapped on various-sized grids (Fig. 1) during late summer and fall. On San Miguel Island, we trapped foxes on four 3 × 6 trapping grids, with 250-m spacing between trap locations. On Santa Rosa and Santa Cruz Islands, foxes were trapped on eighteen 2 × 6 trapping grids, also with 250-m trap spacing. Box traps (23 × 23 × 66 cm, Tomahawk Live Trap Co., Tomahawk, WI) were baited with dry and wet cat food and a fruit scent (Knob Mountain Raw Fur Co., Berwick, PA). Captured foxes were protected from the elements by careful placement of traps and by a shade cloth cover on each trap. A polyethylene tube chew bar was wired inside each trap to reduce incidence of tooth damage. Traps were checked once (in the morning) during every 24-h period. Upon first capture, animals were weighed in the trap and then removed and handled without anesthesia for a complete workup. Data collected included sex-age class as determined by molar wear. Captured foxes were individually marked with passive integrated transponder (PIT) tags (Biomark, Boise, ID) inserted subcutaneously between and just anterior to the scapulae. Each grid on San Miguel was trapped for 5 nights, and each grid on Santa Rosa and Santa Cruz for 6 nights.

Early in the recovery process, when island fox populations were very low, grid sampling was considered an ineffective monitoring method due to the low number of captures and recaptures. During those years, foxes were trapped annually using traps arrayed along road and trail transects, and our estimate of island-wide adult population size was the minimum number known to be alive (MNKA; e.g., the number of individual foxes recorded). We used this method to estimate population size on San Miguel and Santa Cruz from 2004 to 2005 and on Santa Rosa from 2004 to 2008.

We analyzed capture data from Santa Cruz Island grids (2006–2011) using spatially explicit capture-recapture (SECR) models in R (Efford 2010) and data from San Miguel (2006–2011) and Santa Rosa (2009–2011) in program Density (Efford et al. 2004). In such models, captures are a joint function of density (D), detection (g0), and movement (σ) parameters. We used the maximum likelihood estimator and considered each grid to be a separate trapping session. Average adult density from the grids was multiplied by island size to estimate island-wide adult fox population size. Standard errors for average density and island-wide population size were calculated via the delta method (Cooch and White 2006). Because of high variance in pup survival, we removed pups from our analysis to yield a more accurate predictor of extination risk (Bakker and Doak 2009).

Mortality Cause and Survival Monitoring

To estimate survival and identify causes of mortality, mortality-sensing radiotelemetry collars (Holohil Systems Ltd., Ontario, Canada) were placed on a subset of foxes, such that >50 foxes were radio-collared annually on each island. Collared foxes were monitored regularly (every 7–10 days) to determine their general location and signal type (normal or mortality). If a mortality signal was detected, the dead fox was located and recovered. Data collected at the site prior to carcass removal included (1) information that might indicate cause of mortality; (2) notes and digital photographs of the position of the carcass with respect to its surroundings; and (3) the general condition of the animal (e.g., eviscerated, intact, or damaged by insect scavengers). The location of the carcass was recorded via a GPS, and a general description of the habitat was recorded.

Carcasses were tagged with pertinent identification, date, and location information. If fresh carcasses (those located within 5 days of likely mortality) could be brought to the mainland within 48 hours of being located, they were refrigerated, transported to the mainland, and then shipped by overnight carrier to the California Animal Health & Food Safety Laboratory System in Davis, California (Leslie

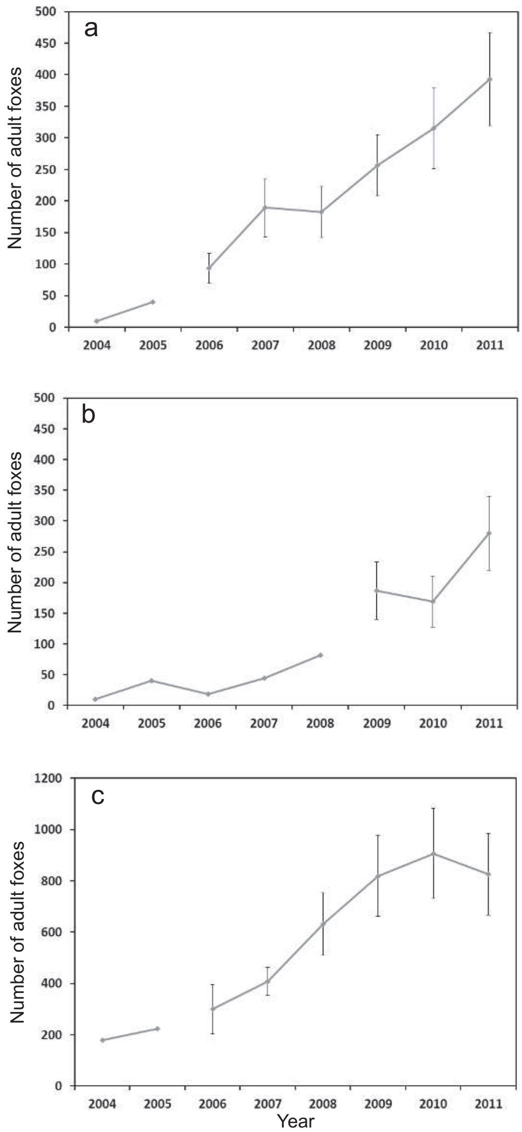

Fig. 2. Annual island-wide adult fox population estimates, 2004–2011: **a,** San Miguel Island; **b,** Santa Rosa Island; **c,** Santa Cruz Island. Eighty percent confidence intervals are provided for population sizes estimated with spatially explicit capture-recapture (SECR) models. Estimates without confidence intervals represent the minimum number known alive (MNKA).

Woods, DVM), for necropsy. Carcasses that were not fresh were frozen and shipped for necropsy at a later date. Because tissue freezing increases autolysis and therefore decreases the amount of data that can be extracted from histological examinations, it was advantageous to have the animal necropsied as soon as possible after death and to avoid freezing if possible. If disease was suspected in the death of the animal, tissues were prepared for histological analysis.

We estimated annual survival of radio-collared foxes using known-fate binomial models (Program MARK; Pollock et al. 1989) and calculated an 80% confidence interval in accordance with the recovery criteria developed for the species (Bakker and Doak 2009).

Risk-based Recovery Criteria

Recent demographic modeling incorporated life-history characteristics of the well-studied island fox with environmental drivers and uncertainty to develop extinction probabilities for combinations of population size and annual mortality (Bakker et al. 2009, Bakker and Doak 2009). The 2 demographic traits that best predicted extinction risk were island-wide adult population size and adult annual mortality rate, assessed jointly (Bakker and Doak 2009). Use of 3-year averages of these parameters allowed for greater resolution in extinction-risk predictions by discounting noise due to stochastic fluctuations. Thus, 3-year averages of both island-wide adult population size and adult mortality became the basis for assessing demographic recovery criteria for the island fox.

Island managers and the Integrated Island Fox Recovery Team identified a predicted risk of quasi-extinction (decrease to a population size of <30) of <5% over 50 years as the population conditions consistent with recovery. To account for uncertainty, the joint 80% confidence intervals for both island-wide adult population size and adult mortality must lie outside the 5% extinction risk isoclines. The recovery team further specified that island fox subspecies must meet this standard for 5 consecutive years before they may be considered for delisting. This standard has now been adopted by the U.S. Fish and Wildlife Service (USFWS) as the demographic recovery criterion in the Draft Recovery Plan for the Island Fox (USFWS 2012). To assess attainment of this criterion, subspecies-specific graphs were developed that plotted risk isoclines across a range of 3-year average adult population sizes and mortality rates.

RESULTS

Estimated island-wide populations of all 3 subspecies increased over time (Fig. 2) due to

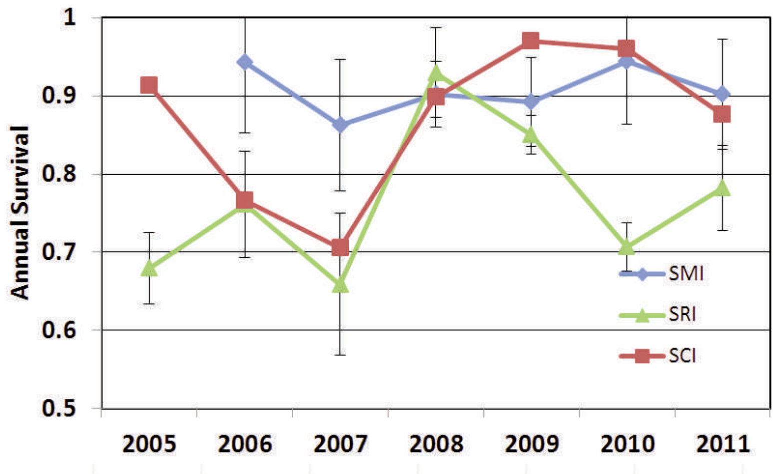

Fig. 3. Annual Kaplan–Meier survival for island foxes on San Miguel (SMI), Santa Rosa (SRI), and Santa Cruz (SCI) islands, 2004–2011.

reintroduction from captivity (2003–2008) and high reproduction and survival in the wild. The average annual rate of increase (λ) was 1.89 for San Miguel, 1.93 for Santa Rosa, and 1.26 for Santa Cruz. Values of lambda >1.0 indicate increasing populations. Excluding 2007–2008, the fox population has steadily increased about 90% per year on San Miguel Island. Annual population growth for Santa Rosa foxes has varied from year to year, with the largest observed growth rate in 2010–2011 following ungulate removal from the island. Annual population growth on Santa Cruz increased an average of 30% from 2005 to 2010.

Throughout the study period, we maintained a sample of >50 radio-collared animals on each island. Annual survival remained above 85% on San Miguel and Santa Cruz islands (Fig. 3), although predation by Golden Eagles decreased annual survival on Santa Rosa Island in 2004–2006 (11 mortalities due to predation) and in 2010–2011 (9 mortalities). No Golden Eagles have attempted to nest on the northern Channel Islands since 2006 (Coonan et al. 2010), and predation on Santa Rosa Island in 2010 was the handiwork of juvenile Golden Eagles (Talbot et al. in preparation).

Necropsy showed no evidence of mortality due to canine diseases, such as canine distemper virus or canine parvovirus. Other notable causes of mortality included septicemia, cholecystitis, and intestinal intussusception on Santa Rosa in 2006 (4 cases) and complications due to leptospirosis on Santa Rosa in 2010 (2 cases).

These relatively high survival rates and increasing population sizes have reduced the predicted probability of quasi-extinction in the next 50 years to <5% for 2 of the 3 northern Channel Islands subspecies (Fig. 4). Both the San Miguel and Santa Cruz subspecies reached that measure of biological recovery in 2009, 10 years after declines were discovered, 5 years after being classified as endangered, and 2 years after captive breeding and reintroduction ceased. Low initial population size and recent bouts of predation prevented the Santa Rosa subspecies from approaching a similar level of biological recovery.

DISCUSSION

Population recovery of the 3 northern island subspecies of island fox has been dramatic and rapid. At their lowest levels, the population sizes of the San Miguel, Santa Rosa, and Santa Cruz island subspecies had dipped to 15, 15, and <100, respectively. By 2011, roughly a decade later, those populations had increased 900%–3000%. By 2011, the adult population had increased to almost 400 adults on San Miguel, which was the approximate adult population size prior to the predation-caused decrease of the mid-1990s (Coonan et al. 2005). On Santa Cruz, the adult population was estimated at >1000 adult foxes in 2012: a size that was approaching the estimated 1994 predecline population high of 1465 adults (Roemer et al. 1994). However, the latter estimate was

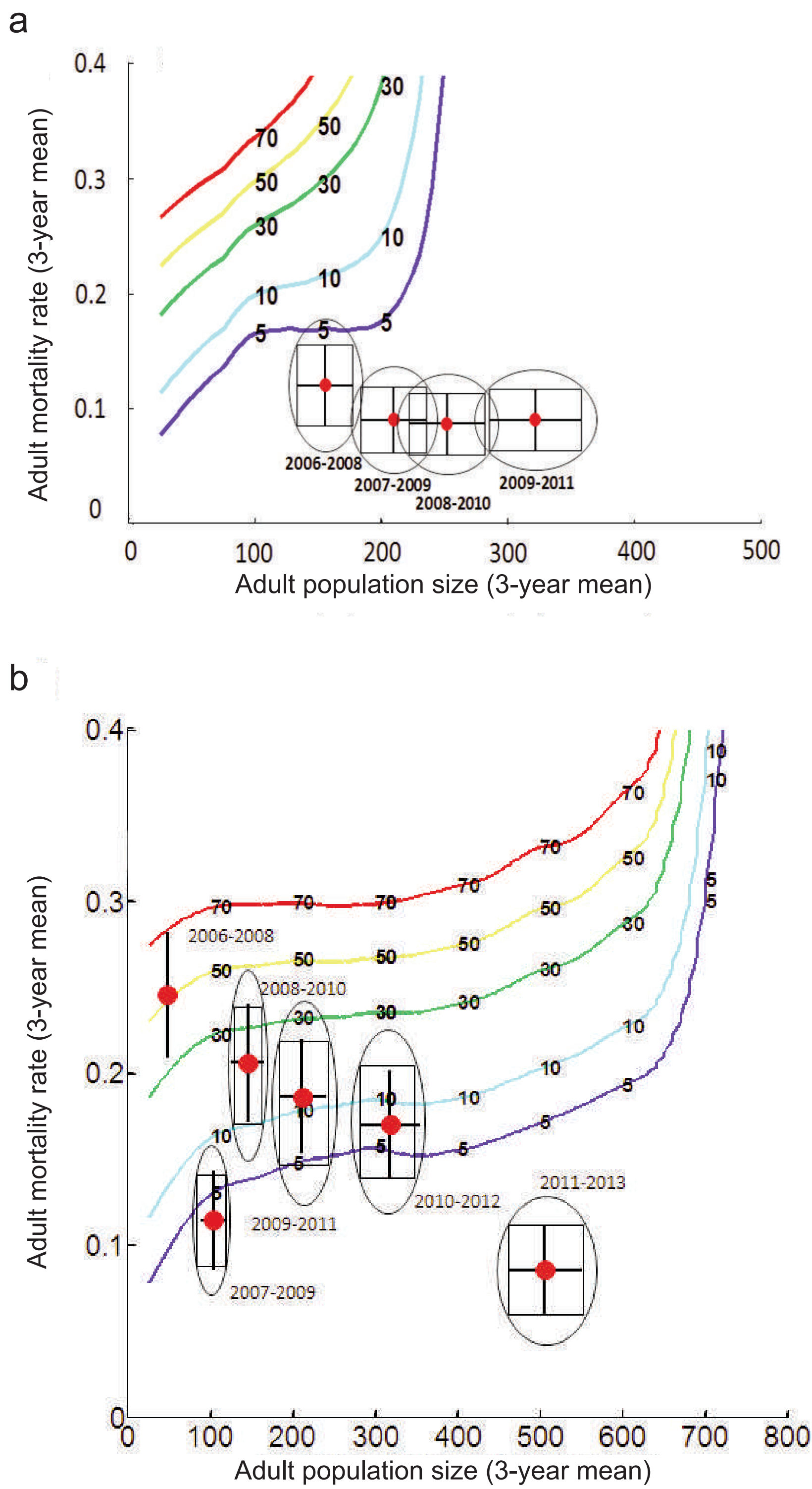

Fig. 4. Caption on page 379.

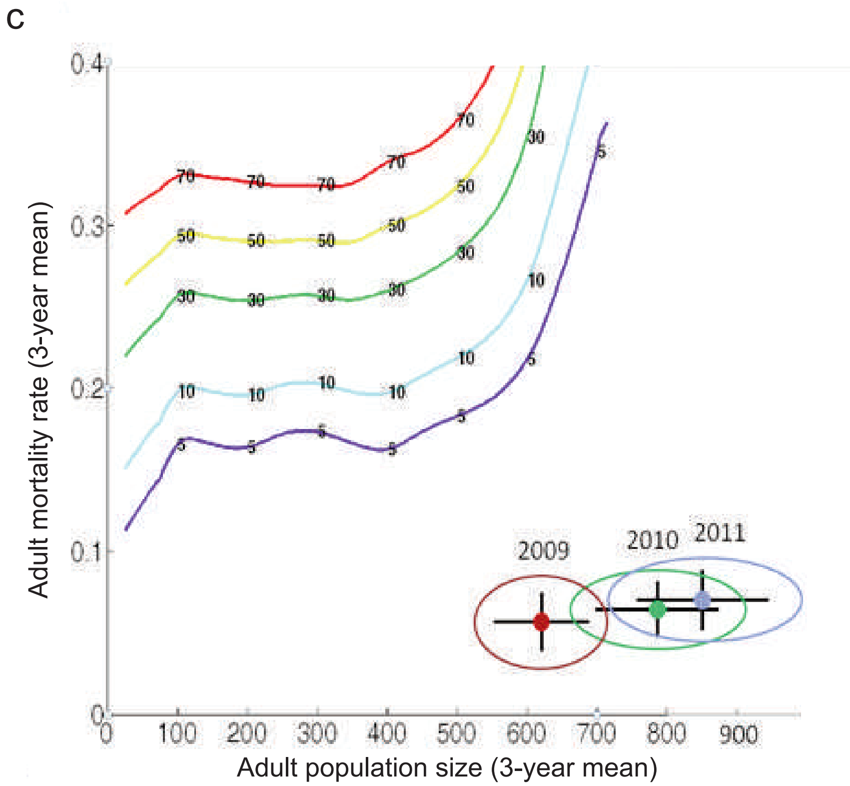

Fig. 4. Risk of quasi-extinction in 50 years for island foxes: **a,** San Miguel Island; **b,** Santa Rosa Island; **c,** Santa Cruz Island.

based on density estimates from only 2 trapping grids and thus may not accurately represent the population size at that time. The predecline estimate of 1780 adult foxes for Santa Rosa (Roemer et al. 1994) may also be an overestimate, since it was based not on field sampling but on average fox densities from neighboring islands with very different habitat composition. Significant eagle predation affected the recovery of Santa Rosa Island foxes in 2004, 2006, and 2010, likely limiting population growth rates. Results from 2012 trapping indicate the adult fox population had increased to >500 (T. Coonan, NPS, unpublished data). Santa Rosa Island is roughly 85% the size of Santa Cruz Island and may have a similar carrying capacity (>1000 as demonstrated by current population estimates). Thus, Santa Rosa Island foxes may still be recovering from the effects of eagle predation.

The rapid population growth rates we report suggest that the northern island fox subspecies may be recovering, but an objective analytical framework is needed to determine when a subspecies has recovered and when recovery actions can cease. Island managers, the National Park Service (NPS), and The Nature Conservancy (TNC) used estimates of island-wide adult population size and adult mortality rates in a recovery tool developed by Bakker and Doak (2009) to demonstrate that the San Miguel and Santa Cruz subspecies have reached a predetermined biological recovery criterion of <5% probability of quasi-extinction over the next 50 years. This threshold has been adopted as a demographic recovery criterion for the species in the draft recovery plan for the island fox (USFWS 2012).

Attainment of biological recovery alone does not guarantee long-term persistence. On these isolated islands, catastrophic mortality factors such as introduced disease and predation by invasive species may negatively impact island fox survival rates. Thus, the USFWS draft island fox recovery plan includes threat-based recovery criteria, such as the implementation of long-term protocols to detect and mitigate disease and predation risk in island fox populations. The draft plan calls for agencies to (1) develop an eagle management strategy that contains response tactics to capture eagles and prevent them from establishing and breeding on the islands, (2) monitor fox populations with sufficient precision to detect a 2.5% predation-caused mortality rate in the island-wide population, and (3) define lower-limit thresholds of survival rate and population size that would trigger a captive breeding effort. Similarly, agencies must develop epidemic response plans that (1) establish a core group of individuals vaccinated against rabies and canine distemper and intended to sustain the population through an epidemic, (2) maintain the ability to detect disease via unvaccinated sentinel animals, and (3) describe a response strategy for detected diseases.

Land management agencies and their partners are currently working to meet these threat-based recovery criteria. An epidemic response plan has been developed for the nonlisted San Clemente Island fox subspecies (*U. l. clementae;* Hudgens et al. 2011), and one is currently being developed for the 3 northern Channel Islands subspecies, as is an eagle response plan for the northern Channel Islands. Land management agencies will continue to collect monitoring data that is used to calculate demographic recovery via extinction risk.

Since 2008, island fox populations have increased enough to allow agencies to halt the most expensive and time-consuming recovery efforts—captive breeding and Golden Eagle removal—and instead focus on creating plans to protect future generations of island foxes from new threats that may arrive via the mainland. Using current demographic trends, we estimate that both the San Miguel and Santa Cruz subspecies will attain the demographic recovery criteria in 2013. Recovery of Santa Rosa Island foxes, which was retarded by eagle predation and low population size, is likely to reach levels indicative of demographic recovery by 2017. The recent removal of nonnative ungulates from that island may increase fox survival and the pace of island fox recovery because the primary attractant for Golden Eagles is gone.

The slide to extinction of island fox was reversed by prompt, intensive, and adaptively implemented interventions by island managers and partners, and the recovery efforts were informed by rigorous population monitoring and modeling. As a result of these efforts, island fox recovery is on track to be one of the fastest for an endangered species. In an analysis of recovery rates for endangered species, Suckling et al. (2012) noted that the average recovery time for endangered species was 25 years. At current survival and population growth rates, the San Miguel and Santa Cruz Island fox subspecies will be considered biologically recovered in 2013, nine years after they were listed as endangered by the U.S. Fish and Wildlife Service, and the Santa Rosa subspecies will be recovered by 2017. Managers now are evaluating how to responsibly scale back monitoring and management intensity on the fox so as to be most effective with the limited conservation funds available for managing island resources. Although recovery actions for the island fox are largely completed, the comprehensive recovery effort has left island managers well-positioned to manage and reduce future risk to island foxes. Over 20 years of previous work on island foxes facilitated the detection of a threat and rapid determination of the cause of population declines. That same research also informed a comprehensive population viability assessment for the species, which in turn allowed development of a tool for unambiguously assessing whether island fox populations are biologically recovered. Moreover, targeted mitigation plans now focus on the most insidious threats to island foxes. From decline through recovery, consistent and standardized monitoring has been a constant; such vigilance will be required, at some level, to see island foxes safely into the future.

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LITERATURE CITED

BAKKER, V.J., AND D.F. DOAK. 2009. Population viability management: ecological standards to guide adaptive management for rare species. Frontiers in Ecology and the Environment 7:158–165.

BAKKER, V.J., D.F. DOAK, G.W. ROEMER, D.K. GARCELON, T.J. COONAN, S.A. MORRISON, C. LYNCH, K. RALLS, AND R. SHAW. 2009. Incorporating ecological drivers and uncertainty into a demographic viability analysis for the island fox. Ecological Monographs 79:77–108.

COLLINS, P.W., AND B.C. LATTA. 2009. Food habits of nesting Golden Eagles (*Aquila chrysaetos*) on Santa Cruz and Santa Rosa islands, California. Pages 255–268 *in* C.C. Damiani and D.K. Garcelon, editors, Proceedings of the Seventh California Islands Symposium, Oxnard, California, February 5–8, 2008. Institute for Wildlife Studies, Arcata, CA.

COOCH, E., AND G. WHITE. 2006. Program MARK: a gentle introduction. 5th edition. Available from: http://www.phidot.org/software/mark/docs/book/.

COONAN, T.J., C.A. SCHWEMM, AND D.K. GARCELON. 2010. Decline and recovery of the island fox: a case history for population recovery. Cambridge University Press, United Kingdom. 212 pp.

COONAN, T.J., C.A. SCHWEMM, G.W. ROEMER, D.K. GARCELON, AND L. MUNSON. 2005. Decline of an island fox subspecies to near extinction. Southwestern Naturalist 50:32–41.

EFFORD, M. 2010. Package 'secr', version 2.5.1. University of Otago, Dunedin, New Zealand. Available from: http://www.otago.ac.nz/density/pdfs/secr-manual.pdf

EFFORD, M.G., D.K. DAWSON, AND C.S. ROBBINS. 2004. DENSITY: software for analyzing capture-recapture data from passive detector arrays. Animal Biodiversity and Conservation 27:217–228.

HUDGENS, B., W. VICKERS, D. GARCELON, AND J. SANCHEZ. 2011. Epidemic response plan for San Clemente island foxes, draft final. Prepared for Naval Facilities Engineering Command Southwest, San Diego, CA. Submitted in fulfillment of Section F.3. of Cooperative Agreement N62473-09-LT-R0004. Institute for Wildlife Studies, Arcata, CA.

KING, J.L., C.L. DUNCAN, AND D.K. GARCELON. 2014. Status of the Santa Catalina Island Fox thirteen years after its decline. Monographs of the Western North American Naturalist 7:382–396.

MORRISON, S.A., N. MACDONALD, K. WALKER, L. LOZIER, AND M.R. SHAW. 2007. Facing the dilemma at eradication's end: uncertainty of absence and the Lazarus effect. Frontiers in Ecology and the Environment 5:271–276.

POLLOCK, K.H., S.R. WINTERSTEIN, AND M.J. CONROY. 1989. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 45:99–109.

ROEMER, G.W., T.J. COONAN, D.K. GARCELON, J. BASCOMPTE, AND L. LAUGHRIN. 2001. Feral pigs facilitate hyperpredation by Golden Eagles and indirectly cause the decline of the island fox. Animal Conservation 4:307–318.

ROEMER, G.W., D.K. GARCELON, T.J. COONAN, AND C. SCHWEMM. 1994. The use of capture-recapture methods for estimating, monitoring, and conserving island fox populations. Pages 387–400 *in* W.L. Halvorson and G.J. Maender, editors, The Fourth California Channel Islands Symposium: update on the status of resources. Santa Barbara Museum of Natural History, Santa Barbara, CA.

SUCKLING, S., N. GREENWALD, AND T. CURRY. 2012. On time, on target: how the Endangered Species Act is saving America's wildlife. Center for Biological Diversity. Available from: http://www.esasuccess.org/pdfs/110_REPORT.pdf

TALBOT, S.L., S.A. SONSTHAGEN, G.K. SAGE, L. PAJOT, B. LATTA, T. COONAN, H. FITTING, AND C. MCINTYRE. In preparation. Species verification and individual identification of eagle feathers dropped at Channel Island fox depredation sites.

[USFWS] UNITED STATES FISH AND WILDLIFE SERVICE. 2004. Listing of the San Miguel Island fox, Santa Rosa Island fox, Santa Cruz Island fox, and Santa Catalina Island fox as endangered; final rule. Federal Register 69(44):10335–10353.

______. 2012. Endangered and threatened wildlife and plants; draft recovery plan for four subspecies of island fox. Federal Register 77(179):56858–56859.

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