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The Island Scrub-jay Faces a Changing Climate

Proactive Conservation Management of an Island-endemic Bird Species in the Face of Global Change

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*Biodiversity conservation in an era of global change and scarce funding benefits from approaches that simultaneously solve multiple problems. Here, we discuss conservation management of the island scrub-jay (*Aphelocoma insularis*), the only island-endemic passerine species in the continental United States, which is currently restricted to 250-square-kilometer Santa Cruz Island, California. Although the species is not listed as* threatened *by state or federal agencies, its viability is nonetheless threatened on multiple fronts. We discuss management actions that could reduce extinction risk, including vaccination, captive propagation, biosecurity measures, and establishing a second free-living population on a neighboring island. Establishing a second population on Santa Rosa Island may have the added benefit of accelerating the restoration and enhancing the resilience of that island's currently highly degraded ecosystem. The proactive management framework for island scrub-jays presented here illustrates how strategies for species protection, ecosystem restoration, and adaptation to and mitigation of climate change can converge into an integrated solution.*

Keywords: Aphelocoma insularis, *climate adaptation, conservation-reliant species, ecosystem engineer, translocation*

The continental United States and Canada have thousands of islands (GID 2011) and over 500 breeding bird species (BNA 2010) but only one insular endemic landbird species: the island scrub-jay (*Aphelocoma insularis*). Its global range, among the smallest of any North American bird, is the 250 square kilometers (km^2) of Santa Cruz Island, approximately 40 km offshore of Santa Barbara, California. Santa Cruz Island lies within Channel Island National Park and is managed jointly by The Nature Conservancy (TNC) and the National Park Service (NPS). Long-term population data are inconclusive about the trajectory of island scrub-jay numbers, so we do not know whether the jay population has been relatively stable or has recently declined. In either case, a consideration of existing and emerging threats and how they are exacerbated by historical land use and anticipated climate change underscores the need for active conservation management.

In the present article, we discuss a range of conventional and unconventional management options for the island scrub-jay. This suite of alternatives constitutes a case study of how species management can be initiated proactively to address foreseeable (as well as unforeseeable) population problems and perhaps thereby reduce the likelihood of future imperilment and the costs and risks associated with endangered species recovery. It also illustrates how a program for species protection can be designed to benefit the broader ecosystem and its associated species. Such precautionary and synergistic approaches are likely to increase in importance for conservation managers, given the myriad mounting and novel threats that species face as a result of climate change.

Conservation status

The island scrub-jay is larger, with a proportionally bigger bill, and is more brightly colored than its closest mainland relative, the western scrub-jay (*Aphelocoma californica*; Curry and Delaney 2002). Its global population size, estimated from islandwide distance-sampling surveys coordinated by TSS, J. Andrew Royle (of the US Geological Survey, Patuxent Wildlife Research Center), and SAM in 2008 and 2009, is estimated to be fewer than 3000 individuals. Earlier, Kelsey and Collins (2000) estimated the total jay population size at 12,500 by extrapolating the area of 23 jay territories to a map of presumed jay habitat across the island. Although we cannot assess whether the jay population declined between the late 1990s and 2008, CTC observed a decrease in the number of breeding pairs in the only research plot monitored between the mid-1990s and 2006. Continued and expanded monitoring on that and other plots since 2007, however, has not suggested a declining population. Regardless of the

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trend, current population estimates are similar to those of other birds federally listed as *endangered* (e.g., red-cockaded woodpecker [*Picoides borealis*]; IUCN 2011). The island scrub-jay, however, is not currently listed as *threatened* by state or federal agencies; IUCN (2011) lists island scrub-jay as *near threatened*. Yet, even if no recent decline has occurred, the vulnerability of the species is apparent, given that its population is small and restricted to a single island.

The island scrub-jay's past distribution highlights its current vulnerability to extinction. Genetic evidence indicates that *A. insularis* and *A. californica* diverged from a common ancestor at least 100,000 years ago (Delaney and Wayne 2005). The island scrub-jay was therefore already a distinct species and presumably had a much larger distribution when sea levels were lower during the last glaciation (20,000–11,000 years ago) and the four northern Channel Islands were connected as a single landmass, Santarosae Island (figure 1; Delaney and Wayne 2005). Interestingly, the only fossil record of island scrub-jays on the northern Channel Islands was found not on Santa Cruz but on neighboring Santa Rosa Island (Collins 2009). The island scrub-jay has therefore already disappeared from a substantial portion of its former range.

Ornithologists assumed for years that the jay went extinct from today's 215-km^2 Santa Rosa Island in prehistoric time (Curry and Delaney 2002), but few intensive biological surveys were conducted on Santa Rosa Island before 1900 (Collins 2009). Even at the middle of the last century, Miller (1951) noted that "the scanty attention given [to] Santa Rosa [results in] the necessary dependence on single reports of occurrence derived from hasty visits" (p. 118). Recently uncovered field notes from one early visitor, a Smithsonian ornithologist who collected birds on the island for three days in 1892, suggest that the extirpation of jays from Santa Rosa Island may have occurred much more recently: Streator (1892), recounting an interview with the manager of the Santa Rosa Island livestock-grazing operation who at the time had been ranching on the island for more than two decades, wrote under the heading of "*Aphelocoma*" that "Mr. John Moore informs me that there are Jays on the island" (Collins 2009). Although the account is anecdotal, the other species that Streator recorded in his notes from that trip as present solely on the basis of interviews were later confirmed to be among the extant fauna of Santa Rosa Island. Streator's visit occurred near the time at which the species was first described by Henshaw (1886) as occurring only on Santa Cruz Island (Curry and Delaney 2002). However, Henshaw never visited Santa Rosa Island and therefore did not have an opportunity to document a jay population on that island, which by then could also have been small and residual (Collins 2009). Sheep (*Ovis aries*) were introduced to Santa Rosa Island in the 1840s; near the end of that century, they numbered between 80,000 and 100,000 and had caused widespread loss of native vegetation. Several endemic forms of birds on the California islands are known to have gone extinct within a century of the introduction of nonnative herbivores (Luna Mendoza et al. 2005, Shuford and Gardali 2008). Habitat destruction by introduced ungulates may well have contributed to the extirpation of the island scrub-jay from Santa Rosa Island.

Figure 1. The California Channel Islands. The global range of the island scrub-jay is currently the extent of Santa Cruz Island. The yellow line depicts the approximate coastline of Santarosae Island, approximately 16,000 years ago. Also depicted is the marine ecoregional divide. The inset shows the location of the Channel Islands in the state of California.

Regardless of how recently the extirpation of *A. insularis* occurred on Santa Rosa Island or whether the cause was natural or related to human activities, the history of avian extinctions on other California islands and the current restriction of the island scrub-jay to one island accentuate the risks to the jay's long-term viability. Climate forecast models, for example, project warmer and drier conditions in southern California (Cayan et al. 2008). Such changes exacerbate threats to the species, such as disease, drought, and wildfire.

West Nile virus (WNV) and other mosquito-borne diseases are expected to become more prevalent with global warming (LaDeau et al. 2008). WNV has already caused acute declines of numerous North American bird populations over the past decade and is particularly lethal for certain members of the avian family Corvidae (LaDeau et al. 2008). The yellow-billed magpie (Corvidae: *Pica nuttalli*), California's other endemic bird species, experienced a roughly 50% decline within three years of exposure to WNV (Crosbie et al. 2008); fortunately, its initial population size and range were at least two orders of magnitude greater than those of the island scrub-jay, and that likely provided demographic buffering for the species' persistence. Although WNV arrived in southern California in 2003 and outbreaks recur annually, extensive screening of passerines and mosquitoes on Santa Cruz Island indicated that, as of late 2009, the disease had not yet become established on the island (Boyce et al. 2011). We do not know whether the island has thus far escaped WNV or whether the virus has arrived but failed to establish itself. One hypothesis for the absence of WNV is that the generally cooler climate on the island relative to the mainland may suppress viral replication in mosquitoes. If Santa Cruz Island is indeed a thermal refugium, this condition is not likely to persist as southern California warms. Moreover, we note that screening of more than 200 island scrub-jays failed to show evidence of other vector-borne diseases known from the nearby mainland (Boyce et al. 2011). Therefore, substantial uncertainty remains regarding the degree to which this small, immunologically naive island scrub-jay population would be able to withstand the appearance of any mainland avian pathogen, let alone WNV.

Warmer and drier conditions may also threaten island scrub-jay habitat by stressing the native vegetation and increasing the vegetation's susceptibility to insect pests and wildfire (UCS 1999). Potential impacts of such threats can be seen on the southern California mainland. For example, a disjunct population of *Agrilus auroguttatus*, a non-native wood-boring beetle, recently established itself and is expanding its range in the mountains east of San Diego; this beetle causes high mortality rates in oaks (*Quercus* spp.; Smith 2009), the dominant genus of native trees on Santa Cruz Island and one whose diversity and abundance is critically important to *Aphelocoma* jays. Multiple catastrophic wildfires have swept coastal southern California over the past decade; in 2003, the wind-driven Cedar Fire near San Diego burned an area equivalent to that of Santa Cruz Island within just 10 hours of ignition. The probability of a large-scale fire on Santa Cruz Island is probably increasing as shrub succession advances and fuel loads accumulate, following the removal of introduced herbivores from the island (figure 2).

In summary, the island scrub-jay is susceptible to a number of classic population problems. It is subject to the vulnerabilities inherent in small, restricted populations, as well as to those of island endemic species generally. With WNV offshore, being a corvid heightens that vulnerability. Especially with climate change, it would be imprudent to assume that threats affecting the mainland will not eventually affect Santa Cruz Island (Bataille et al. 2009). Indeed, *A. insularis* might already best be considered a *conservation-reliant* species (*sensu* Scott et al. 2005), a species for which threats cannot be fully abated and for which human intervention is required for species persistence. At the least, conservation of such species demands ongoing monitoring and a readiness to respond with management. However, rather than waiting for foreseeable population problems to unfold, we suggest that management actions be implemented now to help reduce the likelihood, severity, and cost of these challenges. If the goal is to prevent extinction, a key strategy is to prevent endangerment in the first place.

Management options

We describe four proactive management options for reducing the risk of extinction of the island scrub-jay: (1) captive

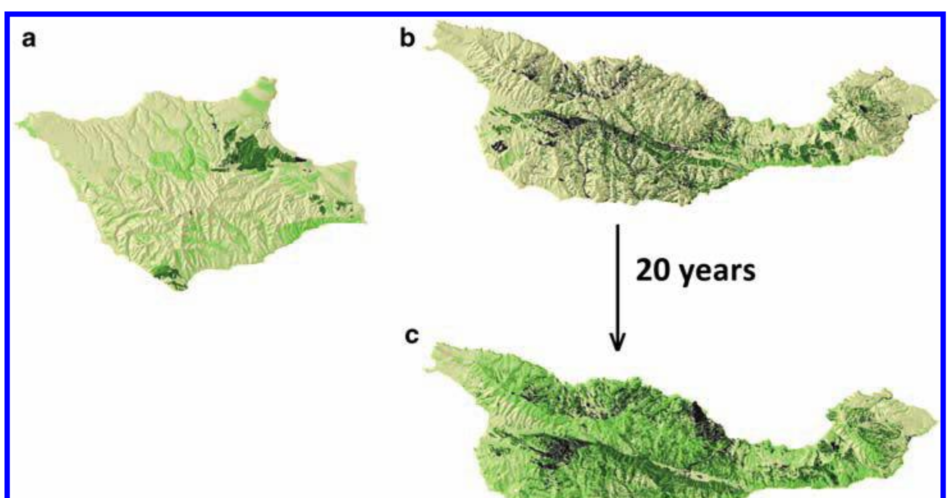

Figure 2. Vegetation coverage of Santa Rosa and Santa Cruz Islands. The vegetation types were categorized as grasses, forbs, or bare ground (beige); shrubs (light green); chaparral or scrub oak (dark green); and woodland (black). The darker colors generally represent better jay habitat. (a) Santa Rosa Island vegetation circa 1988 (adapted from Clark et al. 1990); although more current vegetation maps are not available, vegetation recovery to date has been limited (see Google Earth: 33°57'48.75"N, 120° 6'16.85"W). (b) Santa Cruz Island vegetation circa 1985 (i.e., prior to the removal of feral sheep) (adapted from Jones et al. 1993) and (c) in 2005 (adapted from Cohen et al. 2009).

propagation, (2) vaccination, (3) implementation of biosecurity measures, and (4) the establishment of a second free-living population. We suggest that a rigorous assessment be conducted of the expected return on investment of each option in terms of population viability. The risks and benefits of any action would need to be evaluated relative to those of inaction now and reliance on reactive management strategies later. A program of demographic and genetic research, population and community monitoring, and population and disease modeling is currently underway to inform that assessment. As we discuss below, the policies and conservation philosophies of NPS and TNC also play a part in the evaluation of these options.

Doing nothing is, of course, another management option, but in the case of the island scrub-jay that seems counter to lessons learned from numerous conservation challenges around the world. The potential for a novel disease to have devastating effects on island species is well known. After mosquitoes were introduced on the Hawaiian Islands, avian malaria catastrophically reduced the native avifauna (van Riper et al. 1986). The rapidity and severity of the impact that novel diseases can have on endemic fauna has also been observed on the California Channel Islands: An outbreak of canine distemper virus reduced the Santa Catalina Island subspecies of island fox (*Urocyon littoralis catalinae*) by more than 90% in 1999 (Coonan et al. 2010). Fortunately, that epidemic was disrupted by the narrow isthmus on the island that effectively isolated the foxes residing on the westernmost 17% of the island. The Santa Catalina Island fox is now federally listed as *endangered*, and protection and recovery of the population has required intensive and expensive management interventions, including vaccination and captive propagation programs (Coonan et al. 2010). Clearly, relying on reactive management strategies can be costly and risky, and population structure (in this case, spatial structure) can play a critical role in determining the outcome of catastrophic events.

Captive population programs have been central components of recovery strategies for many species of conservation concern, including Channel Island taxa such as the island fox and the endangered San Clemente loggerhead shrike (*Lanius ludovicianus mearnsi*). Although we have considerable knowledge about the captive management of birds, fine-tuning captive propagation and release techniques can require numerous breeding cycles (Coonan et al. 2010). Research into island scrub-jay husbandry, captive rearing, and release protocols for captive-born individuals while the population is relatively robust would provide preparedness in the event that a larger captive program becomes necessary in the future. A small captive research population can also serve public education purposes. In the context of proactive management actions, a biosecure captive population of island scrub-jays would effectively create a second population, which would increase the chances that some individuals would survive should a catastrophic event befall Santa Cruz Island.

Vaccination is another means to create phenotypic population structure to reduce vulnerability to disease and is a strategy that has been used on other rare or otherwise high-priority species. A subpopulation of each of the four endangered subspecies of island fox is vaccinated against rabies and canine distemper as a central component of that species' recovery strategy (Coonan et al. 2010). A similar vaccination program has been effective in reducing the vulnerability of wild California condors (*Gymnogyps californianus*) to WNV (Chang et al. 2007). A program to vaccinate a subset of the island scrub-jay population has been initiated, aimed at enhancing the likelihood that at least a few hundred jays would survive an outbreak of WNV on the island (Boyce et al. 2011). We emphasize, however, that the desirability of vaccination as a long-term strategy for the jays has yet to be determined; the vaccination effort currently underway is considered to be a precautionary, "better safe than sorry" action ahead of the development of a longer-term management strategy (that may or may not include vaccination against WNV and or other diseases). Moreover, we caution that although WNV vaccine challenge trials have been performed with modest success on western scrub-jays, similar trials have not yet been conducted to investigate the degree of protection that the vaccine confers to the island scrub-jay (Boyce et al. 2011). Performing such challenge trials would presumably be an early component of the longer-term strategy, should a vaccination program be continued.

Development of and adherence to biosecurity protocols designed to prevent, detect, and respond to risks posed by incipient invaders, fire, and pathogens could also reduce risk to island scrub-jay viability. Introduced rats (*Rattus* spp.), for example, have caused avian population collapses on islands around the world. Rats do not occur on either Santa Cruz Island or Santa Rosa Island, but they have invaded four of the other six Channel Islands (one of these infestations has since been eradicated). Efforts to prevent successful colonization by such species can be far more cost effective than reactive threat abatement (Heikkilä 2011). Managers have also made considerable strides in enhancing the quality and quantity of jay habitat on Santa Cruz Island by removing nonnative grazers that suppressed native vegetation (figure 2) and by implementing weed-management programs that may reduce the displacement of native vegetation that is beneficial to jays (like oak chaparral) by nonnative species (such as *Eucalyptus* spp.).

Although we expect that the aforementioned management actions, especially in concert, would reduce the risk of outright extinction, they nonetheless seem insufficient for abating the full array of threats facing the jay. We therefore propose that an additional management option be considered: the establishment of a second free-living population. Wildlife translocations have been used frequently as a conservation management strategy, particularly in the islands of the Pacific. Translocations to islands can be especially effective because they create populations that can be insulated from threats that occur in other parts of the focal species' range.

Establish a Santa Rosa Island population?

Considering the vulnerability of the island scrub-jay to novel threats and catastrophic events, it seems appropriate to evaluate the benefits and risks of establishing a free-living population of island scrub-jays on a neighboring island. We suggest that Santa Rosa Island be considered as the potential location for that second population: There is evidence that the jay once occurred there, and that island has the potential to support extensive jay habitat (unlike the much smaller Anacapa and San Miguel islands; figure 1). Furthermore, establishing an island scrub-jay population on Santa Rosa Island might not benefit only the jay. It could also benefit the ecosystem of that island, which has been highly degraded through overgrazing by introduced herbivores.

At a minimum, the establishment of a Santa Rosa Island *A. insularis* population would increase the total carrying capacity and population size of the species, would decrease environmental correlation, and would add population structure by doubling the number of populations subject to both natural selection and local extirpation. All of these factors increase species viability. The distance between the two islands—9 km—is apparently too far for unaided dispersal by island scrub-jays, but the two populations could be managed as a metapopulation, if necessary, through periodic human-assisted dispersal (figure 3).

Despite the relative proximity of Santa Cruz and Santa Rosa Islands to one another, they actually occur in different marine ecoregions (figure 1; Spalding et al. 2007), and this may have important ecological consequences for the jays and their habitat. The California Current flows southward along central California past Santa Rosa Island, whereas a countercurrent flows northward along the Southern California Bight and Santa Cruz Island, which results in the waters off Santa Rosa tending to be cooler than those off Santa Cruz. Marine conditions have a strong influence on the climate of these islands. Cooler temperatures may benefit the jays by reducing viral replication and thus mosquito-transmitted disease (Boyce et al. 2011). A stronger maritime influence on Santa Rosa Island probably also reduces drought stress (Fischer et al. 2009) and so the risk of whole-island wildfires. Even in the unlikely event that a catastrophic event befell both islands simultaneously, having a greater global population size with a larger and more structured geographic range would reduce the jay's risk of extinction.

Today, Santa Cruz and Santa Rosa Islands are part of Channel Islands National Park. For approximately 150 years prior to their protection as nature reserves, the islands were used for livestock production. Foraging by introduced species, including sheep, cattle (*Bos taurus*), and pigs (*Sus scrofa*), caused widespread destruction of native vegetation (Kindsvater 2006), soil erosion, and the imperilment of many endemic species (Coonan et al. 2010). Most introduced grazers have since been eliminated from the northern Channel Islands; only nonnative deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*) remain on Santa Rosa Island, and they are required to be removed by 2012. Deer and elk currently suppress the regeneration of native scrub and woodland vegetation on Santa Rosa Island (Christian 2009).

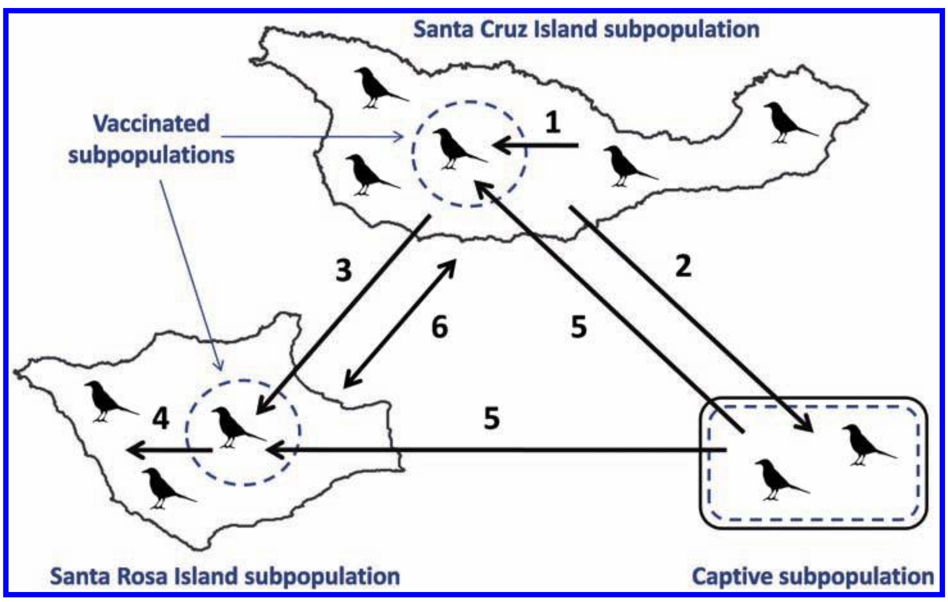

Figure 3. Proposed managed population structure for the island scrub-jay. Absent management, the island scrub-jay would persist as a single population restricted to Santa Cruz Island and vulnerable to a variety of potentially catastrophic islandwide events. With management, a metapopulation with some nested subpopulations would be established. Depicted here, individuals from Santa Cruz Island are captured, banded, and added to the on-island, vaccinated, core population (1), as well as to a (small) biosecure captive research population (2). Individuals from Santa Cruz Island are also used as founders of a population on Santa Rosa Island (3); these individuals would arrive vaccinated, but the population would grow to include nonvaccinated birds (4). Surplus offspring from the captive program would be released back to the island(s), to become members of the vaccinated core population(s) (5). If it were necessary, jays could be moved among the subpopulations (6); population viability and other analyses could help inform the degree to which dispersal among the islands should be facilitated.

Although we expect many vegetation communities to recover after the ungulates are removed from Santa Rosa Island, as has been documented on Santa Cruz Island (figure 2), the extent of jay habitat on Santa Rosa is currently limited (figure 4). Without an active dispersal agent for key plant species, the return of chaparral and forest communities to their former extent is likely to be slow. However, rather than wait for restoration to advance before introducing jays, we note that the jays, if introduced, could help accelerate that restoration (Byers et al. 2006). The scatter-hoarding seed caching behavior of *Aphelocoma* jays is well documented (DeGange et al. 1989) and can be important in the long-distance dispersal of tree seeds (Johnson et al. 2003). Island scrub-jays also forage on—and therefore help disperse—a number of other seed-bearing shrubs and trees. Indeed, the presence of jays probably contributed to the rapid and dramatic recovery of woody vegetation observed on Santa Cruz Island following the removal of feral grazers (figure 2). The value of this ecosystem service provided by the jays, relative to the cost of manual, landscape-scale restoration, can be substantial (Hougner et al. 2006).

Establishing a Santa Rosa Island jay population could also be an important climate adaptation management strategy for the jays—and for the ecosystem of which they would be a part. If WNV risk grades with temperature along the west-to-east axis of the northern islands, moving the jay to Santa Rosa Island may be important for its adaptation to a changing climate, similar to how migration up elevational and latitudinal gradients may be an important climate adaptation strategy for other species. In that regard, if the jays facilitate the movement of keystone plant species upslope (Grinnell 1936), the jays could help other constituents of the Santa Rosa Island community adapt to a changing climate. Broadly, recovery of the native vegetation on Santa Rosa Island is essential in order to increase the island's ecological resiliency and adaptive capacity. Increasing the extent of higher-statured oak- and pine-dominated vegetation would drive restorative feedback cycles, such as increasing moisture harvest from fog, an important water input in this semiarid ecosystem (Fischer et al. 2009). The resulting increase in woody vegetation may also increase the carbon sequestered aboveground in the system (figure 2). Therefore, the establishment of the island scrub-jay on Santa Rosa Island might enhance the viability of that species while also serving as a cost-effective and efficient means of rapidly restoring major components of the island ecosystem, to the benefit of many other native species.

Responsible establishment of any new wild population requires careful assessment of demographic, genetic, and community-related considerations, as well as a framing of the philosophical underpinnings and policy implications of the action (Armstrong and Seddon 2008). NPS policies do not support the experimental manipulation of natural systems. They do, however, support ecological restoration, which has been a central management strategy in Channel Islands National Park. Assessing the potential ecological effect of the jays as predators, competitors, and seed dispersers would be an especially important element in any translocation plan. For example, island scrub-jays are nest predators (Curry and Delaney 2002) and could have negative impacts on naive populations of native songbirds on Santa Rosa Island. However, recent work has shown that endemic avian taxa on the California Channel Islands can exhibit remarkable adaptive plasticity in the face of predation risk from scrub-jays (Peluc et al. 2008). The increase in the extent of scrubland and woodland produced by the jays would also provide additional habitat for a range of endemic taxa. Two vulnerable plant species (IUCN 2011) that have very limited distributions on Santa Rosa Island—island oak (*Quercus tomentella*) and Torrey pine (*Pinus torreyana*, one of the rarest species in the genus)—might especially benefit from the long-distance seed dispersal provided by jays (Johnson et al. 2003). Research and modeling would be needed in order to assess the potential impact of island

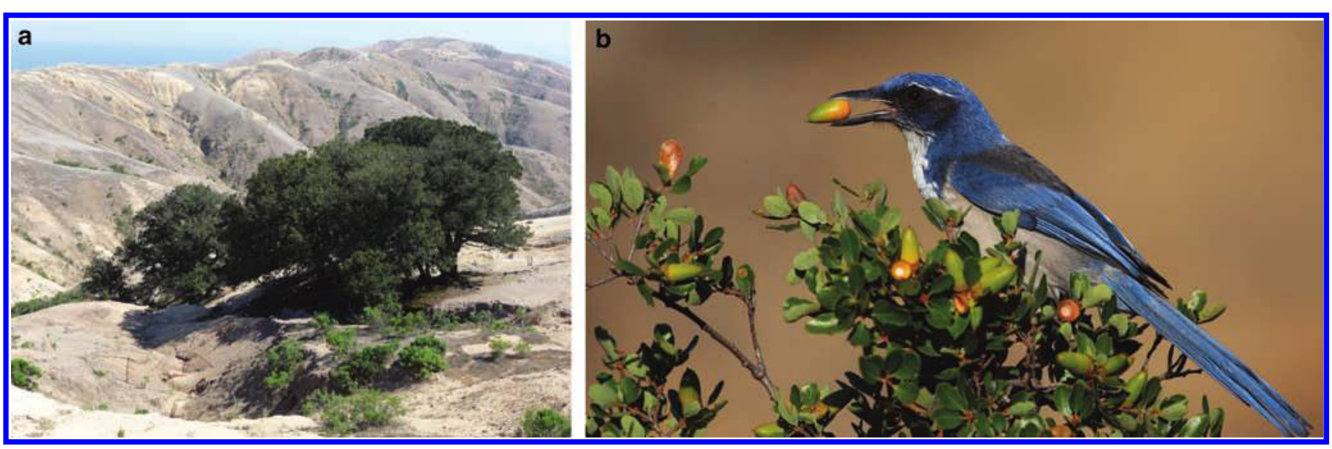

Figure 4. Restoration opportunity on Santa Rosa Island. (a) A remnant oak woodland on Santa Rosa Island, 2008. Vast areas of the island, especially in the higher elevations, have been stripped of woody vegetation. Photograph: Scott A. Morrison. (b) An island scrub-jay with an acorn on Santa Cruz Island. Photograph: Colin Woolley.

scrub-jays on the flora and fauna of Santa Rosa Island, and those impacts would need to be evaluated in the context of the importance of maintaining the full suite of biota native to the northern Channel Islands archipelago more generally. Fortunately, Santa Cruz and Santa Rosa Islands provide an elegant comparative context in which to investigate such issues prior to any decision to establish *A. insularis*.

Management goals in a changing world

Numerous precedents exist for the translocation strategy suggested here (Sutherland et al. 2010). More examples are being contemplated because of concerns about climate change and considerations of the potential return on investment of proactive management action (e.g., Reynolds et al. 2010). Regarding the Channel Islands specifically, the state of California has already suggested the reestablishment of two bird subspecies (the San Clemente spotted towhee [*Pipilo maculatus clementae*] and the Channel Island song sparrow [*Melospiza melodia graminea*]) known to have been extirpated from islands in their former ranges, once the nonnative species that led to those extirpations have been removed and their habitat has sufficiently recovered (Shuford and Gardali 2008).

The unprecedented aspects of the conservation strategy that we present here, however, do warrant special attention. Island ecosystems are by definition idiosyncratic, and that of Santa Rosa is highly altered. Although the restoration of the presumed "natural" vegetation cover observed on Santa Cruz Island (figure 2) provides hope that Santa Rosa Island will rebound in a similar manner, a variety of future states are possible. Because a rapidly changing climate will be the context in which the restoration of Santa Rosa Island will occur, it may behoove managers to consider the degree to which the island has become a novel ecosystem that requires innovative and perhaps more active management approaches (Seastedt et al. 2008). We also note that managers have worked for decades to remove introduced species from the California islands and will surely work for decades more to address persistent and cascading unintended consequences of those species' tenures. Intentionally introducing a species to one of those islands has added significance in this light.

Such uncertainties create conservation and policy challenges and emphasize the need for a rigorous framework for setting management priorities across the Channel Islands. Given the myriad human-induced changes to these ecosystems and to the climate, what should be the conservation goals for the archipelago relative to the individual islands and the various species native to them? Does it matter whether the extirpation of jays from Santa Rosa Island occurred in recent time or whether it was human induced? In the end, the difference between returning the jay to an area it has not occupied for a century and a managed relocation to a region it has not occupied for perhaps millennia may be less a matter of biology than one of philosophy and policy (Richardson et al. 2009, Thomas 2011). Indeed, we have already found that the discussion called for in this article raises fundamental questions about values and the role of protected areas in a dynamic future—questions having real conservation and policy implications (Cole and Yung 2010). What we have also found, however, is that the immediacy and tractability of this particular case provide helpful focus for framing issues regarding climate adaptation that often seem abstract and overwhelming. In a period of rapid change, the most important tools that we have for conserving species are the organisms themselves and their ability to adapt and evolve to changing conditions. Providing secure habitat for species across their full geographical, geophysical, and ecological ranges increases the opportunities that they have to respond to changing conditions and therefore to survive.

Conclusions

The island scrub-jay exists on a single island relatively close to the mainland of southern California. Already of conservation concern because of the jay's small population size and insular range, the long-term viability of this species is further at risk from emerging threats. A major disease rampant nearby underscores the potentially fleeting nature of the opportunity to implement proactive conservation actions. Because evaluating the effectiveness and appropriateness of the different management options discussed here will take effort, as will the implementation of whatever management plan is eventually pursued, time is a critical factor in the conservation of the island scrub-jay.

Precautionary establishment of a second free-living population of island scrub-jays may reduce reliance on an otherwise small set of management options that would be challenged to provide a satisfactory long-term solution. Although the overall management strategy suggested here (figure 3) may appear highly manipulative and would require substantial and sustained programmatic commitment to implement, over the long-term it could be considerably less intrusive, costly, and uncertain than reliance on reactive management strategies. In the 1990s, the San Clemente Island loggerhead shrike population declined to as few as 14 individuals. What pulled the subspecies from the brink of extinction (by 2010, there were roughly 70 breeding pairs in the wild) was an intensive management intervention that involved captive breeding, population monitoring, predator control, and habitat restoration. That recovery program cost $24.7 million between 1993 and 2008 (USDOD 2010). If the suite of management actions that we have discussed for the jay can prevent the need for a large-scale captive breeding program and other labor-intensive population and habitat management efforts, it may be the most effective and efficient way of investing limited conservation resources to achieve multiple conservation goals over the long term. A structured decision analysis of the relative costs, benefits, and risks associated with those management options would be a central component of the assessment called for in this article.

Over the past three decades, managers of the northern Channel Islands have overcome numerous biodiversity crises, from infestations of alien species to the near extinction of native species. The conservation framework presented here provides an opportunity to embark on the next chapter in island management, in which the proactive identification and management of threats, the application of principles of conservation best practice, and the leveraging of ecological knowledge can improve the efficiency and the effectiveness of investments in ecosystem restoration. It may well be that efforts to protect a single species—the island scrub-jay—could be an integral and cost-effective component of a more general plan to restore and enhance the resilience of the broader Channel Islands ecosystem. Indeed, should further analysis support establishing a population of island scrub-jays on Santa Rosa Island, the project could become a model of strategic convergence at the intersection of biodiversity conservation, ecological restoration, and adaption to and mitigation of climate change—a nexus sure to be increasingly important as an overall management and policy goal in the decades ahead.

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