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STRATEGIES FOR BIOSECURITY ON A NEARSHORE ISLAND IN CALIFORNIA

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ABSTRACT.—Islands provide refuge for many rare and endemic species but are especially vulnerable to invasion by nonnative species. Invasive alien species are a major factor in the imperilment and extinction of island biota. Biosecurity protocols are designed to prevent or quickly detect the transport of harmful nonnative species, with the goal of eliminating the high economic cost of invasive species removal and the biological cost of damage caused by nonnative organisms. Effective biosecurity protocols require a balanced approach to on-island monitoring, off-island surveillance and prevention practices, rapid response, and educational outreach. Here we use the biosecurity program on Santa Cruz Island, California, to illustrate how risk evaluation, program priorities, and funding constraints intersect to define programmatic scope. Santa Cruz Island land managers have chosen to invest in early detection programs such as remote camera trapping, off-island prevention and education, and rapid-response planning for rats and in on-island biosecurity to prevent the spread of the most harmful plant species. We suggest that biosecurity efforts will be more effective—as well as cost effective—as an archipelago-wide initiative than as a single-island program. A newly formed collaboration with managers of other California Islands is designed to enhance visibility of the biosecurity initiative and attract new funding sources. With the economy afforded by collaboration, we will expand our program and prioritize annual audits, augment educational programs, measure project success, and increase compliance with and effectiveness of biosecurity protocols.

RESUMEN.—Las islas proporcionan refugio a muchas especies poco comunes y endémicas, y son especialmente vulnerables a la invasión de especies no nativas. Las especies foráneas invasoras son un factor principal en el peligro y la extinción de la biota de la isla. Se designan protocolos de bioseguridad para prevenir, o rápidamente detectar, el transporte de especies no nativas dañinas con el objetivo de eliminar el alto costo económico de la eliminación de las especies invasoras y el costo biológico del daño causado por los organismos no nativos. Los protocolos de bioseguridad efectivos requieren un equilibrio entre el monitoreo en la isla, la vigilancia y las prácticas de prevención fuera de la isla, una rápida respuesta y un alcance educativo. Utilizamos el programa de bioseguridad en la Isla Santa Cruz, California, para ilustrar cómo la evaluación de riesgos, las prioridades del programa y las limitaciones de financiamiento se entrecruzan para definir el alcance del programa. Los administradores de recursos en la Isla Santa Cruz han elegido invertir en programas de detección temprana, como una cámara trampa remota, prevención y educación fuera de la isla, planificación de respuestas rápidas contra ratas y bioseguridad en la isla para prevenir la diseminación de las especies de plantas más dañinas. Pensamos que los esfuerzos de bioseguridad serán más efectivos—al igual que será mas eficiente en términos de costos—con una iniciativa que abarque todo el archipiélago, en lugar de ser un programa para una sola isla. Una colaboración recientemente formada con administradores de recursos de otras islas de California se ha diseñado para mejorar la visibilidad de la iniciativa en bioseguridad y atraer nuevas fuentes de financiamiento. Con los fondos que se obtuvieron de dicha colaboración, expandiremos nuestro programa y daremos prioridad a auditorías anuales, aumentaremos los programas educativos, mediremos el éxito de los proyectos y aumentaremos el cumplimiento y la efectividad de los protocolos de bioseguridad.

Island ecosystems are hotspots of biodiversity (Myers et al. 2000). They also can be especially susceptible to invasion by nonnative species (Vitousek et al. 1996, Fritts and Rodda 1998), which often results in high rates of imperilment and extinction of native biota (IUCN 2012). Over recent decades, advances in eradicating invasive alien species from islands have resulted in considerable conservation gains (Veitch et al. 2011). Increasingly, managers are focusing on preventing such invasions in the first place (Ruiz and Carlton 2003).

Island biosecurity programs are designed to reduce the likelihood of invasive species arriving on a given island and to quickly detect and eliminate those species should they arrive. Prevention and early detection strategies are implemented with the goal of

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reducing the cost of invasive species control, as large-scale and long-term removal of established populations likely requires greater resources (Stohlgren and Schnase 2006). Preventing invasion also avoids potential damage to an island's natural and cultural resources, as well as to human health and well-being. Comprehensive biosecurity plans include the following components: a systematic evaluation of target invasive species and their most important vectors, on-island monitoring at likely introduction points, off-island prevention protocols, educational outreach programs to enlist the cooperation of island users, and rapid-response protocols.

Biosecurity plans have been implemented for islands around the world, including Hawaii and the main islands of New Zealand, as well as offshore islands there and in Australia (The State of Hawaii Department of Agriculture Plant Industry Division 2006, Fritts 2007, Chatham Islands Council 2008, Australian Biosecurity Intelligence Network 2009), but are not yet common for nearshore islands off the U.S. mainland.

Because funding is finite, biosecurity plans are designed to address the greatest risks with some limited and justifiable combination of protocols. Managers should prioritize protocols that help manage the worst or riskiest targets and affect the greatest number of potentially harmful species, and they should allocate resources among techniques that are biologically and site appropriate. To evaluate the riskiness of possible targets, managers should use consistent biological criteria and the best possible data on sites and vectors. In this paper, we define a species as a "high risk" if it (1) has a high likelihood of being transported to a location on-island with suitable habitat or climatic conditions for establishment, and (2) would likely cause significant harm to island ecosystems, if established (Blue et al. 2011).

Resources should be allocated among prevention, early detection, and educational outreach depending on the biology of the invasive targets, likely vectors to the island, size of the island, and probability of detection (Moore et al. 2010). For example, efforts may be best weighted toward on-island monitoring if managers have little ability to quarantine likely vectors and if detectability of new invaders on-island is relatively high. In contrast, detection of small species or those that require specialized knowledge to identify, such as most invertebrates or plants, may be very difficult to detect upon arrival, especially if the island is large. If these species are more likely to be brought to the island with large volumes of people or equipment, off-island quarantine, inspection of gear, and educational outreach may be more effective than on-island monitoring.

California has nearly a dozen offshore islands including the 8 Channel Islands and the Farallons. They range in size from 2.6 km^2 to 250 km^2 and in distance to the mainland coast from 20 km to 120 km. Over 20 million people live along the southern California mainland coast, and thus the potential for human perturbation in these systems is much larger than on more remote islands. Here, we focus on Santa Cruz Island, the largest of California's islands. The Nature Conservancy (TNC) owns and manages 76% of the island; the National Park Service (NPS) owns and manages the remainder. Approximately 40 km from the mainland coast, Santa Cruz Island is visited by roughly 300,000 people per year, with most accessing the island by private concessionaire passenger ferries from Ventura, California (A. Brodie personal communication). Private recreational boats and private aircraft are allowed access to NPS property and access to TNC property provided they have a permit. Due to the volume of visitors, influenced mostly by the island's proximity to the mainland, these human-operated vectors likely pose the most prominent biosecurity risk. Thus, in our protocols we target these vectors over natural vectors such as wind or animal dispersal.

Santa Cruz Island, like all of the California Islands, has been the site of major ecological restoration programs over the past 30 years, including the removal of all introduced nonnative mainland vertebrates (Morrison 2007), the eradication or on-island control of nonnative, habitat-modifying plants (Cory and Knapp 2014, Powers et al. 2014), and the elimination of nonnative honeybees. Numerous native species have benefited from these restoration efforts (e.g., Corry and McEachern 2009, Sillett et al. 2012, Coonan et al. 2014), which represent substantial investments of time and funds. TNC and NPS have committed to implement biosecurity protocols to protect that investment and the resulting conservation gains and also to control the spread of invasive species to unaffected island sites and reduce the risk of reinfestation from the mainland (Boser et al. 2014, Cory and Knapp, 2014).

Proactive biosecurity efforts underway on Santa Cruz Island for nearly a decade have prioritized protocols that seek to prevent the establishment or spread of species considered most threatening to island-wide recovery. Santa Cruz Island's biosecurity program was formally launched in 2004 when Channel Islands National Park commissioned the nonprofit conservation organization Island Conservation to write a biosecurity plan for the 5 islands within the national park; that plan focused on preventing the invasion and spread of nonnative mammals such as rats (*Rattus* spp.; Howald and Creel 2004). TNC developed an invasive plant management plan in 2007 which outlined management actions to prevent the establishment of nonnative plants and to eradicate or control selected invasive plant species (Knapp et al. 2007). A 2011 report created decision support tools for Santa Cruz Island land managers to select appropriate biosecurity protocols by estimating the biological risk posed by select species and vectors (modes of transport), assessing potential quarantine and monitoring protocols, and carrying out cost-benefit analyses of the protocols (Blue et al. 2011). The authors evaluated 20 species and identified *Rattus* spp., Cape ivy (*Delairea odorata*), New Zealand mudsnail (*Potamopyrgus antipodarum*), and canine-vectored diseases as the high-risk invaders for Santa Cruz Island. With limited funding available to prevent nonnative invasive species introductions, TNC and NPS land managers have prioritized the protocols that would reduce the likelihood of introducing these harmful species.

Below we discuss the protocols we have implemented on Santa Cruz Island to target high-risk species, including examples of early detection, prevention/educational signage, rapid-response planning, and on-island biosecurity of localized invasive populations with control or eradication techniques. In 2012 we began an archipelago-wide collaboration with other California Island land managers, the California Islands Biosecurity Working Group. This collaboration is designed to benefit all the native communities on the California Islands as the land managers jointly develop a comprehensive biosecurity plan that strengthens their individual programs using pooled resources and combined expertise.

Biosecurity Programs on Santa Cruz Island

Early Detection: Remote Camera and Chew Card Monitoring

Early detection strategies should be implemented for high-risk species when all likely vectors cannot reliably be accessed with prevention protocols. On Santa Cruz Island, the priority target invasive taxon is *Rattus;* and the likelihood of introduction by unregulated means, such as private recreational or fishing boats, is so high that we have implemented an on-island detection program in conjunction with traditional off-island preventive measures (described in the next section). *Rattus* species are difficult to detect and have devastated the native biota of many temperate, tropical, and subarctic islands around the world (Russell et al. 2005, 2008, Broome 2007, Jarrad et al. 2010). Although this protocol was designed to target *Rattus* species, it would equally detect many invasive mammal species if present.

In 2011 we initiated our remote camera monitoring protocol at likely introduction points around the island. Private vessels were selected as the target vector because rats and other mammals are capable of swimming from an anchored vessel to shore (Russell et al. 2005). In fact, at least 2 invasive raccoons (*Procyon lotor;* native to mainland California, but not native to any of the California Islands) were observed swimming to a neighboring island from anchored private vessels (J. King personal communication). We considered likely introduction points to be island locations <500 m from the ocean and in close proximity to areas frequently visited by private sailboats and other vessels (as mapped by satellite data). We distributed these points in such a way that maximized island-wide coverage.

Rats display an aversion to new items in a previously explored environment (Barnett 1958). We used noninvasive camera traps baited with scent lures and, understanding that we might be placing a camera in the established territory of an incipient rat, we used long intervals between trap checks to allow a possibly resident rat to become comfortable with the device, thus increasing the probability of detection.

Limited by funding for cameras and project time to deploy those cameras, we chose to place 15 remote-sensing Reconyx Inc. cameras in a new location every 3–6 months (September 2011, November 2011, March 2012, October 2012, and March 2013). Cameras recorded one digital photo each time the motion-sensing or heat-sensing trigger was activated. The cameras were equipped with an infrared flash, allowing for night monitoring. We used a helicopter to access many locations, thereby avoiding disturbance to surrounding habitat and difficulties usually associated with accessing remote areas by boat or trail. Within the optimal viewing area, at 3 m in front of the camera, a scent lure (Hawbaker's muskrat lure—tested and used to lure in rats on San Miguel Island, USA) was deposited on lamb's wool under a wire-mesh square. We placed rocks over the mesh to ensure that island foxes (*Urocyon littoralis*) could not disturb the lure. As evidenced by consistent visitation to the lure by native foxes and skunks, these lures remained attractive for the 3–6 month duration of the camera set. At the end of each monitoring period, we removed the cameras, downloaded the data, and within a day redeployed the cameras to new locations. Thus we were able to survey points at reasonably short-distance intervals along the entire island's shoreline within a 1-year time frame. With increased program funding, we could reduce the time interval between camera checks and redeployment.

Minimizing data requirements and thus data processing time allowed us to reduce the cost of the project. After collecting the cameras deployed in September 2011 and November 2011, we reviewed the camera data in Adobe Photoshop Lightroom 4 and cataloged the species in each photo. We concluded that the cameras were functioning adequately, so cost-cutting measures were implemented. Photos were no longer individually cataloged by species but were only reviewed to detect invasive species, which reduced photo processing time from 30 hours to 2 hours.

Concerned about the possibility of a camera malfunctioning at a given site, we evaluated redundant, inexpensive, and simple secondary detection techniques. Hair snares were considered but were rejected because of the concern that rats would only use designs that would be overwhelmed by island fox use and island fox hair. We decided to use chew cards, intended to draw in mammals which then bite on the baited card and leave a tooth imprint. The tooth imprint (width of the incisors) of a large invasive rodent can be distinguished from that of the small native rodents (e.g., mice; Sweetapple and Nugent no date). Chew cards were made of corrugated plastic cut into 2 × 4-inch rectangles. One end was dipped into a melted solution of 1 part peanut butter and 3 parts sugar and the other end into muskrat lure (Sweetapple and Nugent no date). We zip-tied 10 to 20 cards to vegetation at each monitoring location. After collection, most chew cards contained tooth impressions of island foxes and of mice. No invasive mammal tooth imprints were ever detected at any of the remote locations. To reduce total project cost, chew cards were not cataloged by species. It is likely that the low number of native mammals on this island increased our ability to quickly assess the cards for the presence of invasive mammal tooth impressions.

To date, we have rotated the 15 cameras to a total of 70 locations and reviewed data from 55 of those locations. The data were fully cataloged after the first 2 deployments (and 8 months of data) such that at 29 monitoring locations, a total of 24,582 digital photographs and 400 chew cards were analyzed for evidence of invasive species (Table 1). A total of 7460 digital photographs were triggered by a variety of fauna (Table 1) over an 8-month period (3330 camera nights). Fortunately, no sign of rats or other invasive species was detected. A few cameras were responsible for a high percentage of misfires which is an indication that some camera placements were not ideal and that loose vegetation frequently triggered a photo (Table 1).

The cameras could likely be left on-site to collect data for at least a year. After 4 months of deployment between November 2011 and March 2012, camera batteries were nearly fully charged and the 4 GB memory cards were on average only one-eighth full. The benefits of detecting an incursion in a timely fashion must be weighed against the financial cost of frequently accessing and replacing the cameras.

Off-island Prevention and Educational Outreach: Gear Checks and On-island Signage

Gear checks and biosecurity education are key programmatic elements designed to

TABLE 1. Data collected from remote camera monitoring efforts August 2011–March 2012 at 29 locations on Santa Cruz Island, California. In addition to the fauna categories listed here, photos were obtained of invertebrates ($n = 10$), herpetofauna ($n = 6$), and field technicians ($n = 246$). In some cases, multiple species were detected in the same photo.

Site	Total photos	Camera misfire	Island fox	Spotted skunk	Deer mouse	Raptor	Passerine	Sea bird	Chew cards retrieved
1	4135	4034	84	2	2	0	2	0	20
2	13	10	0	0	3	0	0	0	11
3	250	5	245	0	0	0	0	0	21
4	36	5	20	11	0	0	0	0	11
5	255	9	177	19	21	0	0	3	17
6	0	0	0	0	0	0	0	0	10
7	463	253	140	1	2	0	70	0	7
8	73	10	61	1	0	0	1	0	20
9	63	21	32	0	5	0	5	0	10
10	1132	72	950	0	11	0	66	0	30
11	628	627	1	0	0	0	0	0	12
12	161	36	58	6	50	0	7	0	17
13	0	0	0	0	0	0	0	0	6
14	23	0	23	0	0	0	0	0	20
15	509	497	7	1	0	0	4	0	19
16	214	40	184	0	1	0	2	0	3
17	250	28	88	0	0	6	11	0	16
18	2028	1130	607	8	56	0	5	0	12
19	245	31	161	4	0	0	0	0	17
20	384	136	72	0	0	0	69	0	17
21	64	18	24	0	0	0	17	0	10
22	209	14	110	0	37	0	33	0	8
23	318	5	180	15	0	0	0	0	13
24	130	16	77	0	35	0	0	0	18
25	1016	634	61	20	56	24	134	0	13
26	2364	1934	369	8	0	0	31	0	10
27	8104	7285	479	104	53	38	29	0	14
28	355	3	325	0	1	0	2	890	11
29	1160	68	26	0	1	0	0	890	7
TOTAL	24,582	16,921	4561	200	334	68	488	1783	400

prevent the transport of small propagules and cryptic species. NPS, TNC, and the private concessionaire passenger service, Island Packers Company, have agreed to a list of items that are likely to transport high-risk species (e.g., *Rattus* spp., weeds, insects, and New Zealand mud snail) and have prohibited those items from the transport vessels. Clothing and gear checks at NPS boats and concessionaire locations are implemented primarily by volunteers working for NPS or the private concessionaire. The volunteer personnel look for protocol violations and suggest alternative packaging or sanitary procedures wherever possible.

To address the risk of canine-borne diseases to the island, we have implemented an on-island educational outreach effort targeting recreational boaters. Pets are not allowed on the NPS or concessionaire boats, thus private vessels are the most likely vector of the high-risk canine diseases. In 2011, we posted educational signage at the 3 most popular anchorages with information for boaters describing the dangers of transporting companion animals to the island. Specifically, the signs inform boaters that pets arriving from the mainland could carry diseases that could infect the native, endangered island fox. The island fox population on neighboring Santa Catalina Island experienced a precipitous decline in 1999 (Coonan et al. 2010) due to a disease likely vectored from the mainland. By explaining the rationale behind the island-wide prohibition of companion animals, we hope to gain broader compliance with rules regarding pets.

We have developed educational materials explaining the threats posed by hitchhiking weed seeds and placed the information in trail guides and TNC-issued landing permits, which must be obtained by private boaters before visiting TNC property. These materials describe the restoration work that has occurred on Santa Cruz Island over the last 30 years and highlight the need for all visitors to actively protect the island from invasive species.

TABLE 2. Weed species targeted for eradication by The Nature Conservancy on Santa Cruz Island, California.

Scientific name	Common name
Acacia decurrens	Green wattle
Acacia melanoxylon	Blackwood acacia
Albizia lophantha	Plume acacia
Carduus pycnocephalus ssp. *pycnocephalus*	Italian thistle
Centranthus ruber	Red valerian
Cortaderia selloana	Pampas grass
Ehrharta erecta	Panic veldt grass
Eriogonum giganteum var. *giganteum*	Saint Catherine's lace
Ficus carica	Fig tree
Genista monspessulana	French broom
Hedera canariensis	Canary Islands ivy
Helichrysum petiolare	Licorice plant
Malva assurgentiflora	Catalina mallow
Oenothera xenogaura	Beeblossom
Olea europaea	European olive
Opuntia ficus-indica	Mission cactus
Pelargonium x hortorum	Garden geranium
Phalaris aquatica	Harding grass
Pinus pinea	Italian stone pine
Rubus armeniacus	Himalayan blackberry
Schinus molle	Peruvian peppertree
Solanum elaeagnifolium	White horse nettle
Tamarix ramosissima	Tamarisk
Washingtonia robusta	Mexican fan palm

Rapid Response Planning: Rat Detection Kit

A rapid response plan should be enacted for high-risk species that reproduce or spread quickly and thus require removal soon after first detection. A proactive, rapid response plan could include obtaining detection supplies and compliance documents for eradication. On Santa Cruz Island, there were annual unconfirmed rat sightings in 2009–2012, and it was necessary for land managers to quickly assess the veracity these sightings. In 2011, we developed a rat rapid response kit which is readily available in the event a rat is reported. The kit includes materials and protocols used to initiate camera trapping (4 remote cameras, AA batteries, memory cards, bungee cords, and the remote camera monitoring protocol described above) and live trapping (10 Tomahawk collapsible traps for squirrels and Hawbaker's muskrat lure) to detect invasives and investigate the magnitude of an infestation. The kit is located on the mainland so that it is available for deployment to any of the California Islands within a day of a report. The kit is a first response tool used to document presence of rats, if they exist. If an infestation is detected, an eradication effort would entail a larger response including lethal traps and rodenticides. Currently, TNC and NPS do not have federal or state compliance documents in place that would allow use of broadcast rodenticides on the Northern Channel Islands. However, it is a goal of the California Islands Biosecurity Working Group (see section below) to obtain those permits that would allow for a rapid eradication response.

On-island Biosecurity: Detecting and Treating Localized Populations of Invasive Plants

For islands that host small populations of ecologically destructive invasive species, on-island biosecurity in the form of control or eradication may be crucial to protect native species assemblages. On Santa Cruz Island, invasive plant mapping and treatment targets specific weeds for eradication. We designed our methods (1) to prevent the establishment of new populations of target invasive species, (2) eventually eradicate these species from the localized areas where they have established, and (3) search for unrecorded populations of novel weed species.

A risk assessment of established invasive plant species was conducted for Santa Cruz Island to guide the on-island biosecurity efforts. An island-wide weed map and weed management strategy completed in 2007 (Knapp et al. 2007, 2009) documented the locations of 55 habitat-modifying weed species, representing nearly one-third of the known nonnative plants present on the island (Junak et al. 1995). From that list of 55 invasive plants, we targeted 24 for eradication based on their population size and their potential to outcompete native species (Table 2). The eventual success of the eradication effort hinges on our ability to detect new populations that may establish due to a latent seed bank, arrival from the mainland via wind or ocean currents, or animal-mediated transport (bird excrement or human clothing/equipment). Thus, we invest a significant amount of searching and treatment effort each year so that gains made in previous years are not lost.

In 2010, we initiated a program to search for new populations of targeted weeds near 10 commonly used anchorages, assuming that these weeds might be vectored to the island by private boaters and ocean currents. The detection methods we employed allowed us to search for novel species in addition to the target invasives. Ten new populations of targeted invasives were documented and treated that year, and no novel weeds were detected. The effort was considered effective at those sites but limited in island-wide efficacy, because we did not survey introduction points via vectors such as bird excrement or wind.

In 2010–2011, we conducted a search for new target invasive populations concurrently with our annual remote weed eradication efforts (Cory and Knapp 2014). We accessed known populations of target weed species via helicopter. Varying the flight path in and out of these locations allowed us to search for new populations of unrecorded target species and incipient problem species around the areas where our target weeds had at one point been introduced. We believed these areas might be prone to future introductions or experience resurgence from existing seed banks. We detected 162 new populations of our targeted weeds, treated them, and entered their locations into our weed database so they could be annually monitored and treated as needed to ensure eradication. This technique required more effort and was considered more effective at finding and treating new populations primarily because it allowed a greater area to be surveyed.

THE FUTURE OF BIOSECURITY: COLLABORATION

Early detection and prevention efforts, educational outreach, rapid-response plans, and on-island biosecurity programs collectively represent the first phase of biosecurity action for Santa Cruz Island. Additional proactive planning and vigilance are needed, as some priority species and target vectors are not sufficiently monitored by current protocols. Regular program audits must be prioritized to ensure up-to-date threat protection. Although measurement is difficult, managers should attempt to quantify biosecurity program success. Additional components of biosecurity programs are time intensive and expensive, and economy is required if we are to implement these critical priorities. Currently the California Island land managers are working independently to combat invasive species introductions on individual islands. We suggest that a second phase of biosecurity protection is required: one that pools available resources and expertise among the California Islands to more economically implement effective biosecurity protection and attract funding opportunities.

Internal audits of biosecurity programs are critical to compliance and programmatic longevity. Managers should perform regular assessments to evaluate levels of incursion risk against the resources available to combat invasive species (Blue et al. 2011). Protocol selection should be reassessed and target organisms reevaluated to ensure an effective program. Efficacy should be quantified by data when available or by manager consensus. Currently there is no formal audit of the Santa Cruz Island biosecurity program, but we are reviewing the biosecurity programs for individual California Islands and will reassess, condense, and develop archipelago-wide procedures during that process.

Quantifying the success of biosecurity programs is difficult because the desired result is nondetection of invasive species. Off-island prevention protocols are not often able to capture data on the likelihood of stowaway species being detected but rather are designed to be effective in entirely preventing transport of contaminated materials. Data for on-island early detection programs often are not analyzed to determine detection probability, and financial constraints frequently limit the monitoring data that can be collected. Thus, by default, managers generally assume that a lack of detection indicates a lack of invasive species presence. We are more capable of evaluating the success of educational outreach with before and after surveys designed to capture changes in public attitudes or actions. In 2014, we will expand our educational outreach in collaboration with other California Islands and conduct these surveys as a component of that outreach. However, those data will only illustrate changes in visitor behavior and will not quantify the number of species prevented from establishing on islands as a result of the educational campaign. Thus, the survey data is an indirect way of ascertaining the ecological effects of prevention efforts and should properly be characterized as a measure of visitor awareness. Considering these data gaps, we must recognize that the decisions to implement protocols are usually resource- or preference-driven rather than data-driven. As we develop a more streamlined biosecurity program, care should be taken to gather efficacy data wherever economically and logistically feasible.

The history of invasive species removal, conservation management, and initiation of proactive biosecurity is not unique to Santa Cruz Island but is a story shared by all California Islands. Similar biosecurity protocols such as invasive species prevention, weed management, and biosecurity education are already in place on each island. There is growing recognition that managers may accrue a myriad of benefits by coordinating their biosecurity efforts. Economies of scale may be achieved by developing shared educational materials and a common set of monitoring protocols. Likewise, rat detection kits and other rapid response materials can be shared among partner islands when the need arises, thereby reducing duplicate efforts. To this end, in 2012, managers and partners of the California Islands formed the California Islands Biosecurity Working Group, which will collaborate on a number of biosecurity initiatives, including the development of a comprehensive biosecurity plan for the archipelago. This cooperative effort will incorporate the most effective biosecurity protocols from among the islands, enhance our ability to secure funding for these initiatives, and provide a voice for biosecurity to concessionaires, island users, the public, and regulatory agencies. Further, this collaboration represents a defining transition in conservation management on the California Islands: since many of the nonnative invasive species that had demanded intensive and reactive crisis management are now removed, going forward, managers can focus on proactive prevention of threats to the exceptional conservation values of the archipelago as a whole.

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