Western North American Naturalist 78(4), © 2018, pp. 959–972

Connecting island communities on a global scale: case studies in island biosecurity

Juliana Matos[1,*], Annie Little[2], Keith Broome[3], Euan Kennedy[4], Federico A. Méndez Sánchez[5], Mariam Latofski-Robles[5], Robyn Irvine[6], Chris Gill[7], Aurora Espinoza[8], Gregg Howald[9], Katrina Olthof[10], Morgan Ball[10], and Christina L. Boser[1]

[1]*The Nature Conservancy, Ventura, CA*
[2]*U.S. Fish and Wildlife Service, Ventura, CA*
[3]*Department of Conservation, Hamilton, New Zealand*
[4]*Department of Conservation, Christchurch, New Zealand*
[5]*Grupo de Ecología y Conservación de Islas, A.C., Ensenada, Mexico*
[6]*Parks Canada, Skidegate, British Columbia, Canada*
[7]*Coastal Conservation, Tappen, British Columbia, Canada*
[8]*Servicio Agrícola y Ganadero, Chile*
[9]*Island Conservation, Santa Cruz, CA*
[10]*Wildlands Conservation Science, Lompoc, CA*

Abstract.—Invasive alien species represent one of the greatest threats to island ecosystems and the unique species that inhabit them. In many instances, eradication or control programs for invasive alien species have effectively curtailed the ongoing loss of biodiversity on islands. Prevention is a more proactive and cost-effective approach, however, and is an emerging global priority in the conservation of island ecosystems. Island biosecurity programs attempt to prevent the introduction and establishment of invasive alien species on islands and dictate actions when an invasive species is detected. Targeted and robust collaboration efforts among the global island community on biosecurity advances and challenges can strengthen and improve local biosecurity programs. In this paper we review the principal tenets of island biosecurity—prevention, detection, and response—using case studies of current island biosecurity programs from New Zealand, Chile, Mexico, the United States, and Canada. Systematic evaluations of biosecurity activities are necessary to ensure that programs are effective and relevant. Key priority actions for the future include strengthening global collaboration on biosecurity through holding annual meetings, sharing resources online, leveraging funding opportunities, and forming working groups that will be engaged in improving critically important but under-resourced biosecurity programs.

Resumen.—Las especies exóticas invasoras representan una de las mayores amenazas para los ecosistemas insulares y para las especies endémicas de las islas. En muchos casos, los programas de erradicación o de control de dichas especies, redujeron efectivamente la constante pérdida de biodiversidad en las islas. Sin embargo, la prevención es un enfoque más proactivo y rentable, y una prioridad mundial emergente en relación a la conservación de los ecosistemas insulares. Los programas de bioseguridad insular intentan prevenir la introducción y el establecimiento de las especies exóticas invasoras, y llevar a cabo acciones cuando se detecta la introducción de una especie invasora. Las labores sólidas y precisas de colaboración de la comunidad insular global relacionadas a los avances y a los desafíos de bioseguridad pueden fortalecer y mejorar los programas locales. En este documento, revisamos los postulados principales de la bioseguridad en islas: prevención, detección y respuesta, utilizando estudios de caso de programas de bioseguridad en islas, que incluyen a Nueva Zelanda, Chile, México, Estados Unidos y Canadá. Es necesario llevar a cabo evaluaciones sistemáticas de las actividades de bioseguridad, para garantizar la efectividad y la relevancia de los programas. Las medidas prioritarias para el futuro, incluyen el fortalecimiento de la colaboración global en materia de bioseguridad, mediante reuniones anuales, intercambio de recursos en línea, aprovechamiento de oportunidades de financiamiento y grupos de trabajo dedicados a mejorar los programas de bioseguridad, que no cuentan con recursos suficientes, pero que son de gran importancia.

Invasive alien species (IAS) are ranked as one of the greatest threats to island species and ecosystems (Howald et al. 2007, Reaser et al. 2007, Aguirre-Muñoz et al. 2016). Increased global trade has accelerated the rate of IAS transport, resulting in increased vulnerability

*Corresponding author: juliana.matos@tnc.org

RI orcid.org/0000-0002-6008-1864

of island systems (Early et al. 2016). Moreover, endemic island species are disproportionally affected by IAS impacts because population size and genetic diversity are limited, and species are often restricted within niche habitats on the island itself (Loope and Mueller-Dombois 1989). Invasive species impacts have significantly contributed to the extinction rate of island species, estimated to be nearly 80% of known global extinction events (Sax and Gaines 2008). The introduction of IAS can result in direct and indirect impacts to island biodiversity through predation, introgression, competition for limited resources, habitat alteration, and ecosystem degradation (Vitousek et al. 1996, Williams and Basse 2006). Invasive alien species negatively impact human livelihoods through disease transfer, food insecurity, property damage, agricultural degradation, and loss of cultural identity and resources (Reaser et al. 2007, Pejchar and Mooney 2009). Invasive species are a global problem, with the annual cost of impacts and control efforts equaling 5% of the world's economy (Pimentel et al. 2001). Governments and land managers are increasingly prioritizing biosecurity to protect the investments made into IAS eradication and habitat restoration programs on islands.

Island biosecurity is now prioritized in regional and federal government initiatives, policies, and international agreements because it is recognized as a cost-effective tool to protect biodiversity. The United Nations Environment Program's working group, the Convention on Biological Diversity, is a leading global authority and outlines a framework on global biodiversity in its Strategic Plan for Biodiversity 2011–2020. This plan outlines targets and strategies that include topics in biosecurity. Specifically, Aichi Biodiversity Target #9 states that "by 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment" (CBD 2017). Across the North American continent, biosecurity is a focal area of the Trilateral Island Initiative, an effort to promote the conservation and restoration of island ecosystems and their adjacent coastal and marine environments in Canada, the United States, and Mexico (Trilateral Committee 2017). At the programmatic level, countries including Mexico, New Zealand, and Canada have developed national strategies to address island biosecurity (Environment Canada 2004, National Advisory Committee on Invasive Species 2010, MPI 2016, DOC 2017). For example, an arm of the New Zealand government known as the Ministry for Primary Industries is tasked with outlining and implementing New Zealand's biosecurity programs.

Collaboration in the global island community is crucial to the success of biosecurity programs. Through the knowledge-sharing of challenges, advances, and lessons learned, island resource managers are better equipped to prioritize and pursue biosecurity actions effectively and efficiently. As part of the effort to share information and enhance collaboration between countries, practitioners working on islands across the Pacific Ocean were invited to participate in a biosecurity session at the 9th California Islands Symposium held in Ventura, California, in 2016. An outcome of this session was the creation of an international Island Biosecurity Working Group whose goal is to increase collaboration and strengthen biosecurity programs on a global scale. Current participating countries include Canada, the United States, Mexico, Chile, and New Zealand.

Although regional biosecurity practices vary, a island biosecurity program generally comprises 3 central tenets: prevention, detection, and response (Russell et al. 2008). Here we present case studies from the symposium biosecurity session that highlight important advances in these 3 areas. We also identify priority actions to improve collaboration and access to biosecurity resources.

PREVENTION

A rigorous prevention and quarantine protocol that minimizes the threat of IAS introduction to island ecosystems is the most cost effective of the 3 biosecurity program components and warrants sustained investment over time (Stohlgren and Schnase 2006). Prevention concentrates efforts on human-assisted pathways of IAS, such as mainland harbors, airports, maritime vessels, and aircraft. Prevention activities include quarantine, biosecurity inspections, and education. For the purposes of this paper, education and outreach strategies are identified as a subtenet of prevention. Recommendations for prevention activities vary depending on island vulnerability and uses such as tourism, research, residency, conservation, or military training. For primarily touristic islands, such as those located off the coast of New Zealand, the vectors most likely to introduce IAS are the gear and apparel of visitors and the crafts transporting them to and from the islands. Military islands, such as San Nicolas Island off the coast of California, have a greater risk of IAS introduction through vectors such as large-scale cargo shipments from international ports. The most effective prevention protocols vary depending on the vector. Although the principles of prevention have been well understood for some time, the tools and methods are still in development, reflecting (1) a growing maturity in biosecurity awareness and (2) the social and technical complexities of managing the risks. To provide further insight into the spectrum of prevention methods implemented around the world, this section explores case studies from islands off the coasts of New Zealand, Mexico, and the United States.

Protecting the Pest-free Islands of Hauraki Gulf, New Zealand

The Hauraki Gulf (4000 km^2) is the commercial seaway to Auckland, which is New Zealand's most populous city, foremost tourist destination, and major departure point for the nation's greatest concentration of boat users of all kinds. The gulf is also a marine park within which biosecurity must be managed for 44 pest-free islands and 15 other biologically significant islands under differing forms of ownership. Most of these islands are in public tenure and managed for recreational or conservation purposes by the central government through the Department of Conservation (DOC) (Bassett et al. 2016). The regional government's Auckland Council has jurisdiction over the remaining islands, including those that are privately owned, through rules governing natural resource uses in the gulf. The open islands—many of which are biological sanctuaries—receive hundreds of thousands of visitors annually, arriving on commercial ferries or private vessels. The risks from largely unregulated public and commercial traffic are complex to manage.

Biosecurity defenses of pest-free islands in the gulf are growing in reach and sophistication on several fronts. The Auckland Council and the DOC share practices that are subject to systematic improvement and that minimize the biosecurity risks associated with their own contact with the sensitive islands (Broome and Kennedy 2013). Typically all DOC and Auckland Council cargo traveling to the Hauraki Gulf islands is inspected at the DOC's dedicated quarantine location in Auckland and held in secure storage until departure (Broome 2007). Residents on some islands also submit their freight to quarantine voluntarily. Wherever possible, the high-risk cargo (e.g., overnight luggage, machinery, and farm supplies) and lower-risk cargo (e.g., day visitors' personal gear) of residents and visitors to open islands are inspected at points of departure by dogs trained to detect rodents, the most likely stowaways. Visitors are likely to be asked before and during their voyages to check their belongings for other stowaways, including invasive plant seeds, reptiles, and small insects. This is especially the case if visitors are traveling by commercial ferry, because such messaging and inspection is a condition of the right of ferries to convey passengers to the islands.

The Hauraki Gulf has a special incentive program for commercial supply and transport companies. Companies are encouraged to apply for a pest-free warrant (PFW) which obliges them to comply with basic biosecurity measures, including the use of pest-free supplies, vessels, and vehicles (Bassett et al. 2016). The PFW is a 12-month certification granted to commercial vessel owners and their contractors who meet all requirements during an annual biosecurity inspection. In some cases the PFW is a condition of the companies operating a concession, and the DOC checks regularly to ensure compliance. In return, PFW holders enjoy a marketing advantage as a trusted or preferred supplier, making it a win-win situation.

Behavior-change programs for New Zealand recognize the vital distinction between generalized public outreach and messaging tailored carefully to the particular needs and beliefs of each type of island visitor. Generalized outreach in the gulf is coordinated under the *Treasure Islands* brand, which can be found on everything from billboards to rat bait stations. The *Treasure Islands* campaign is a joint initiative between the DOC and the Auckland

Council to protect conservation islands in the Hauraki Gulf (DOC 2017). The campaign aims to create public awareness of pest-free islands in ways that emphasize their social and ecological benefits. The brand offers consistent messaging about pests, simple predeparture quarantine, and reporting of incursions. Initiatives of this sort seek more than elevated awareness (Lysnar 2016); they aim for enduring forms of beneficial behavior from visitors of differing backgrounds who may not be intuitively receptive to conservation and biosecurity messages.

The DOC has commenced 2 social research projects aiming for behavior change in specific types of visitors to open islands. The research is using community-based social marketing methods to determine what messages will (1) convince recreational boat users in New Zealand's Bay of Islands to leave their dogs at home rather than land them on sensitive kiwi-crèche islands (Ough Dealy and Greig 2016) and (2) encourage recreational boat users of all kinds to check their crafts and gear for pests before leaving home. Though these projects are just beginning and their effectiveness has not yet been quantified, their pursuit is vital to preventing the introduction of invasive pests to the islands in the Hauraki Gulf.

Collaboration to Prevent IAS Introductions, Mexico

Mexico's coast is unique in that it borders 4 bodies of water: the Pacific Ocean, the Gulf of California, the Gulf of Mexico, and the Caribbean Sea. There are more than 4000 islands, islets, cays, and reefs in Mexico, with 14 times more endemic species on islands than the mainland (Aguirre-Muñoz et al. 2016). The Baja California Pacific Islands alone have 50% more endemic species of vertebrates and plants per unit area than the Galapagos Islands (Aguirre-Muñoz et al. 2011). Several of the Baja California Pacific Islands have recently been declared as biosphere reserves by the Mexican government. The Mexican islands support a wide range of artisanal and sustainable fishing cooperatives as well as tourism.

Mexico has a successful 20-year trajectory of island restoration (Aguirre-Muñoz et al. 2016); implementation of the National Strategy on Invasive Species (National Advisory Committee on Invasive Species 2010) aims to enhance local capacities of IAS management. The National Commission for Knowledge and Use of Biodiversity (CONABIO, La Comisión Nacional para el Conocimiento y Uso de la Biodiversidad) coordinates the national strategy while the Global Environment Facility through the United Nations Development Program funds the program. The Grupo de Ecología y Conservación de Islas, A.C. (GECI; a Mexican civil society organization), executes the island-related portion of the program.

Six islands have been chosen to be pilot project areas; these are priority areas, all of which are protected federal territories managed by the National Commission for Protected Areas (CONANP, La Comisión Nacional de Áreas Naturales Protegidas). These 6 islands have had successful eradication projects in the past, including the removal of donkeys, horses, dogs, goats, sheep, cats, mice, and black rats (Aguirre-Muñoz et al. 2016). All of the islands are regularly visited by fishermen, some islands have naval personnel permanently living there, and some islands are tourist destinations. Therefore it is necessary that each island's managers make certain that every sector is included and understands how to help keep the islands free of IAS.

Mexico's unique bottom-up strategy conveys the importance of biosecurity by involving individuals at every level. Biosecurity workshops are held on each island to build local capacity and to collaboratively formulate biosecurity protocols ad hoc. The Mexican Navy, park managers, port authorities, and local communities are invited to these workshops. The Protected Area Advisory Council—comprising researchers, representatives of the local community, and leaders of economic sectors (e.g., tourism)—is also invited to participate in designing biosecurity protocols. These groups collaborate on setting priorities, identifying "critical control points" where biosecurity measures must be set in place, and determining what methods should be used. A separate biosecurity committee is in charge of implementing and evaluating the biosecurity protocols.

Various outreach activities related to IAS prevention and biosecurity are held within the local community with the motto "island conservation is in our hands." Both children and adults are able to participate in workshops at schools, local events, and environmental fairs where art meets conservation and where activities are designed to raise awareness about the importance of biosecurity. To date, the GECI has organized 17 biosecurity workshops all over the country, involving 137 park rangers and managers. The GECI has also formulated 6 unique biosecurity protocols for islands by setting priorities for prevention measures using the most cost-effective and site-specific tools and methods.

Although informal implementation of the protocols is already ongoing, it is important to designate a trained point person who will carry out biosecurity inspections and reinforce prevention measures with visiting tourists. The topic of biosecurity has become common among officials and residents of the Mexican islands and is now viewed as an important need in order to protect the unique ecosystems. These outreach efforts have resulted in 5 cases of passive early detection and rapid response, meaning that a member of the local community informed island officials of suspected rat evidence, which led to a response effort. Three of the passive early detection alerts were false alarms and 2 resulted in the capturing of individual rats that had eluded prevention measures. Thus the involvement of the local community has proven to be vital for the islands to remain IAS-free.

Preventing Introductions of IAS to San Nicolas Island, United States

Naval Base Ventura County San Nicolas Island (SNI) is the fifth largest of the 8 California Channel Islands and is located approximately 100 km off the coast of southern California. The island is owned and managed by the United States Navy and is used for research and development of weapons and tracking systems. The strategic importance of SNI is characterized by its ability to provide a safe and highly instrumented volume of air and sea space in which to conduct controlled tests and operational training while maintaining environmental resources. San Nicolas Island is home to many thousands of marine mammals, endemic plants, important seabird nesting colonies, an endemic subspecies of the island fox (*Urocyon littoralis dickeyi*), and a host of nonvascular plants (Ramsey et al. 2011). The island is one of 5 Channel Islands that does not have a known population of rats (*Rattus* sp.). Rats, invertebrates, and invasive plant seeds have been identified as the ranking biosecurity threats to the island.

Anthropogenic vectors to SNI include a variety of aircraft and a barge. Commercial and recreational vessels are not permitted within 275 m of the island and vessel groundings are uncommon. The island is not open to the public and only receives personnel in support of mission-related activities. Common shipments to the island include heavy machinery, vehicles, dumpsters, flatbed trailers with various equipment, one-ton bags of gravel, and food supplies.

To reduce the likelihood of accidental IAS introductions, cargo is inspected at the barge and aircraft staging areas on the mainland before being transported to the island. If potential biosecurity threats are detected, biosecurity contractual requirements and an order signed by the base's commanding officer grant the inspector permission to either remove the threat or notify the shipping party that the shipment will not be transported until the cargo is biosecure. The barge and the staging areas on the mainland are equipped with rodenticide stations and/or snap traps, and small mammal trapping occurs annually at the staging area to assess the abundance of rats in that area. To further reduce the likelihood of rats persisting at the staging area, riprap crevices are filled with concrete and debris piles are removed.

The navy's environmental division actively works to reduce risks to SNI through action and education. Biosecurity brochures and posters are located at passenger terminals and cargo shipping facilities, and all staff involved in the cargo shipping process are required to view a presentation on the importance of biosecurity and their role in preventing the introduction of nonnative species. In-person briefings on the natural resource program and biosecurity priorities occur on-island, during which all personnel take part in a mandatory footwear inspection to search for soil and IAS seeds.

Since 2009 the navy has intercepted alien spiders and termites, invasive plant seeds, and soil. Footwear inspections have revealed hundreds of IAS seeds in the laces, collars, tongues, eyelets, linings, and soles of boots. Rodent trapping on the barge traveling to SNI has resulted in 11 deer mice (*Peromyscus* sp.) captured in live traps on 8 occasions. Although it is likely that these were endemic SNI deer mice, this result demonstrates how easy it is for small mammals to move with cargo and emphasizes the importance of continued biosecurity monitoring and inspection efforts both to and from the mainland.

Education and Outreach as a Means of Prevention on the Pribilof Islands, United States

The Pribilof Islands are a remote group of 4 volcanic islands (200 km^2 in total area) located in the Bering Sea approximately 320 km southwest of Cape Newenham, Alaska. More than 2.7 million seabirds and gulls breed on the islands, including 80% of the world's population of Red-legged Kittiwakes (*Rissa brevirostris*). The Pribilofs' economy is heavily dependent on the commercial fishing of snow crab (*Chionoecetes opilio*) and Pacific halibut (*Hippoglossus stenolepis*).

In an effort to keep the islands free of invasive rodents, the city governments of St. Paul Island and St. George Island have passed ordinances banning rodent-infested ships from entering the harbor and have instituted biosecurity programs for onshore fish processing companies. The U.S. Fish and Wildlife Service has invested in maintaining an invasive rodent–free status for the Pribilof Islands through prevention techniques and community education. Furthermore, the St. Paul's Tribal Ecosystem Conservation Office and the St. George Traditional Council have operated a successful rat-prevention program for decades that includes snap traps in the industrial areas of the harbor. Despite these efforts, however, the accidental introduction of nonnative house mice (*Mus musculus*) on St. George Island in 2014 reinforced the need for the entire community to be involved in prevention programs.

The goal of the education and outreach project on the Pribilof Islands is to change behavior and increase understanding within the communities so that the introduction of rats or other IAS is viewed by the community as a problem with significant ecological impacts. The project focuses on educating children in the Pribilof School District by (1) developing a curriculum that explores the impacts of introduced IAS on biodiversity and what can be done to prevent IAS such as rats from becoming established and (2) providing valuable hands-on opportunities for the children to learn about the global importance of the Pribilof Islands for breeding seabirds and the vulnerability of seabirds to IAS.

The project was a collaborative effort that involved education specialists and experts on seabirds and IAS from several organizations. The school curriculum demonstrated that the use of activities including art, drama, and hands-on experiences are powerful educational tools that effectively kept the children engaged throughout the lessons. Bringing teachers into the planning process early on ensured that the lessons were effective and relevant to the community and culture.

Surveys indicated that students on St. George and St. Paul Islands gained awareness of the global importance of the Pribilof Islands to nesting seabirds and the vulnerability of seabirds to IAS through the school curriculum, seabird camps taught by the Seabird Youth Network (seabirdyouth.org), and community events such as Bering Sea Days. Students were tested prior to and after the program on their knowledge of endemic species (including seabirds), the vulnerability of endemic species to invasive rodents (particularly rats), and biosecurity activities. Tests showed over 80% improvement on "rat facts" and nearly 40% improvement on "biosecurity facts" after the program. This project demonstrates that education may be helpful in preventing invasive species introductions in residentially populated island communities.

Early Detection

Early detection systems are used in situ as second lines of defense to detect IAS arrivals and to identify the organism so that responses are rapid and appropriately targeted. These early detection programs must be funded and operated with sufficient capacity to respond to IAS with measures proportional to the severity of the introduction risk. That is, species that spread slowly or have a high probability of detection may require less rigorous early detection systems than species that rapidly spread or are difficult to detect.

Early detection methods include remotely triggered camera traps, rodent chew cards or blocks, tracking cards, trained detection dogs, and routine surveys via foot, airplane, or helicopter. Detection systems should be sufficiently sensitive in order to avoid ambiguous evidence of pest arrival. Remotely triggered cameras traps are noninvasive and relatively labor free (Boser et al. 2014, Meek et al. 2014). Because cameras are used to detect incursions by mobile vertebrates, the rapidity of image assessment is crucial to the success of this early detection method. In contrast, early detection of invasive plants may result in effective removal of the threat if the plants are detected within a few months to several years after the introduction and if a significant seed bank has not developed.

The availability of WiFi coverage and advances in camera technology have improved the capacity to conduct timely image reviews by making it possible to send images in real time (Meek and Pittet 2014). Though advancements in technology have been made, there is a pressing need for island managers to invest in research and development (R&D) to help develop technologies that will allow for earlier detection of IAS, even for low-density populations. Conservationists in Africa have developed satellite-enabled wildlife camera traps to detect poachers in real time throughout remote areas of Kenya's Tsavo National Park. Though this technology is not currently available for commercial purchase, investing in the expansion of satellite-enabled cameras could make this resource affordable for and easily accessible to island managers. Satellite transmission is an especially appealing option in countries like New Zealand where steep topography and isolation conspire against more conventional copper wire and mobile network options.

In addition to investing in R&D to develop faster image retrieval technologies, it is just as important to invest in quicker image analysis processes. Depending on the wildlife activity and the environmental factors creating false triggers (e.g., vegetation swaying in the wind), a single camera may produce upwards of thousands of images each week, making it challenging to review all of the images and to determine whether there is an IAS present. To address this issue, The Nature Conservancy is exploring software development to train image recognition software to identify the species present in the island camera traps and to ultimately send a notification to the biosecurity manager if a suspected IAS is detected in the images.

Early Detection in the Archipelago Juan Fernández, Chile

The Archipélago Juan Fernández is a group of 3 volcanic islands in the South Pacific located approximately 670 km off the coast of Chile. This island group has the most endemic plants per square kilometer—nearly 64% of the native flora species are endemic—than any other islands in the world (Valdebenito et al. 1992). Because of its unique ecology, the archipelago is considered a "biodiversity mini hotspot," making it a conservation site of global importance (Funk and Fa 2010). It has been identified as one of the 12 most threatened national parks in the world (Allan 1985), with 80% of its flora species threatened mainly by IAS. The archipelago is currently a biosphere reserve and a national park, which provides Chile the ability to prioritize conservation in this multiuse landscape.

Robinson Crusoe Island, the main island within the archipelago, has a permanent population of approximately 1000 individuals, with the main uses of the island being tourism, lobster catching, and other fishing activities. The 2 greatest threats of IAS introductions to the archipelago are from the transportation of passengers and gear by boat and aircraft from the mainland. To address these threats, the Ministry of Agriculture and the Municipality of Juan Fernández are collaborating to create the Oceanic Islands Commission (OIC) working group. The group's mission is to protect biodiversity and renewable resources through the implementation of communication, mitigation, and monitoring plans.

A recently proposed resolution will regulate the entry of materials from the mainland to the archipelago based on a risk analysis of potential IAS introductions. The risk analysis will identify the potential pathways of IAS introduction, the risks associated with each pathway, and management strategies for each risk. The resolution will regulate the entry of cargo, passengers, and passengers' baggage and will prohibit the entry of 14 plant species considered to be pests. Any species not included in the resolution will require a risk analysis before being transported to the archipelago.

Chile has successfully detected IAS introductions through surveillance activities, which complement the regulation of cargo, as stated in the resolution. Surveillance activities consist of surveying the flora and fauna at over 60 specified checkpoints within the island group, including areas of interest, areas at a high risk of IAS introduction, and areas with visitor presence. Throughout the archipelago, surveillance activities have detected 12 bird, 2 reptile, 1 mammal, 7 arthropod, 1 mollusk, and 29 plant species that are nonnative. These data will be used to inform the resolution.

Early Detection of Invasive Plants on Santa Cruz Island, United States

Santa Cruz Island is the largest of the 8 California Channel Islands and is co-owned by The Nature Conservancy (TNC) and the National Park Service (NPS). The island supports more than 600 plant species in 10 different plant communities (Junak et al. 1995). Human occupation has resulted in both intentional and accidental introductions of invasive plant species that threaten native plant communities/species and alter ecosystem processes.

The Invasive Plant Eradication Program on Santa Cruz Island began in 2007 with the creation of an invasive plant map which was the result of surveying the entire island for 55 invasive plant species deemed to be priorities. Over 5000 infestations were documented (Knapp et al. 2009). The map was initially used to target 14 species for eradication. Since 2007 an additional 18 species have been added to the eradication target list (Cory and Knapp 2014). The effort utilizes a helicopter to deploy technicians to the targeted populations, a technique that has the added benefit of facilitating incidental aerial surveys of the island. During semiannual helicopter use by trained aerial survey biologists, an additional 120 infestations were detected between 2008 and 2015 (J. Knapp, personal communication, 2015). In each case the new invasive plant infestation was added to the list of eradication targets, monitored, and annually treated if necessary. These incidental observations helped justify a second invasive plant census in 2015; the island was systematically surveyed in its entirety and a number of new populations of known species were detected, such as new populations of carnation spurge (*Euphorbia terracina*) in 2 watersheds and expanding populations of sweet fennel (*Foeniculum vulgare*) on the west end of Santa Cruz Island. The populations were detected early enough to initiate control to zero density if repeated treatment visits are made (Wildlands Conservation Science 2015). This effort highlights the importance of periodically surveying for invasive plants or invasive animal sign in conjunction with other incidental observations during ongoing field surveys.

To augment the early detection program, TNC biologists created field-ready invasive plant identification cards that are available online and distributed at island housing. The cards are used to train biologists with other expertise (e.g., wildlife biologists) on the physical descriptions of invasive plant species targeted for eradication as well as those not yet observed on Santa Cruz Island but known on neighboring islands and the mainland.

Response

If an IAS is detected on an island, the extent of the infestation, rate of spread, and risk of dispersal must be assessed to determine whether a response action is feasible and ecologically beneficial in the balance of impacts. Confirming the identity of the IAS is critical before launching a full response protocol. For instance, responses differ for invasive mice versus rats; extensive time and effort can be wasted trying to locate the wrong organism. Furthermore, having predetermined and clear lines of communication among decision-making entities will facilitate an efficient and rapid response. An action and communication flow chart that has been preapproved by regulatory agencies and land managers may be used to plan a response and may be especially useful in cases when action must be taken quickly or when a number of the decision-makers may be unavailable (Boser et al. in press). With the understanding that nontarget species may be impacted during response actions, mitigation measures and decision points should be mapped into the flow chart to assess the ecological cost of various actions relative to the benefits of removing or controlling the IAS. To avoid unnecessary delays, it is particularly important to prepare for upscaling of the response should initial measures fail. In the U.S., advance permitting and environmental compliance are being considered to facilitate an effective rapid response. One of the complexities of proactive permitting is the difficulty of providing the level of detail required by the permitting process regarding elements such as the seasonality, location, potential impacts, and extent of a potential IAS introduction.

Responding to an Incursion of Stoats on Kapiti Island Nature Reserve, New Zealand

Kapiti Island (19.65 km^2) is a pest-free island of enormous cultural and biological significance to New Zealand. The island is a nature reserve for critically threatened biota and lies 5 km west of the North Island near the city of Wellington. Kapiti Island offers crucial sanctuary to a range of threatened bird species, including more than 80% of the world's population of Little Spotted Kiwi (*Apteryx owenii*). As with all other kiwi species, this alarmingly rare kiwi cannot survive in the presence of mustelids.

In 2010 a stoat (*Mustela erminea)* was detected on the island, making stoats the first mammalian pest since the eradication of Norway rats (*Rattus norvegicus)* in 1996. Stoats are willing and competent swimmers, but reaching an island more than 3 km offshore was without precedent and thus completely unexpected. The DOC staff responded to the sighting report, confirmed the presence of stoats on the island, and persisted in eradication efforts until succeeding. The sighting required an effective response in order to eradicate the stoats before they could breed and establish. Effectiveness was urgent for 2 reasons: (1) eradication best practices were inadequately defined at the time and (2) stoats are known to be intractable targets.

The project team adopted a modified Coordinated Incident Management System (CIMS) to bring better structure and rigor to the response. The nationally dispersed CIMS team convened regularly by phone conference and prepared an action plan that was updated continually to include new knowledge and contingencies. A technical advisory group supported relationships with the media and island stakeholders and was crucial to the success of the project. The group's advice was integral in matching what could be achieved logistically with the realities of defeating the ecology of the target species (Brown et al. 2011).

The DOC used trapping as its principal tool, supplemented by dogs trained to detect stoats. Three stoats were captured over 10 months at a cost of 600,000 NZD, which is approximately 415,000 USD. Success was declared after an additional 18 months of monitoring with traps and detection dogs. Genetic analyses of captured stoats provided critical intelligence about the target population during the operation, such as the sex and familial relationships between individuals. In some cases, DNA was used to identify prey items in the gut of captured stoats (Brown et al. 2012).

The stoat-removal project highlighted the importance of maintaining detection and eradication infrastructures so that response plans can be activated without delay. In this example, the eradication effort was delayed significantly by the need to reopen the island's neglected trails. Today trail maintenance is a priority contingency measure on pest-free islands. The project also confirmed the benefits of the CIMS approach to provide sound planning, systematic operations, and the grounding of tactics in expert advice.

Rapid Response to an Incursion in Arrecife Alacranes, Mexico

Arrecife Alacranes National Park is the biggest coral reef structure in the Gulf of Mexico and comprises 5 islands: Chica (1.3 ha), Pájaros (2.8 ha), Pérez (17 ha), Muertos (15 ha), and Desterrada (29 ha). These islands are vital nesting sites for seabirds including the Masked Booby (*Sula dactylatra*), Brown Noddy (*Anous stolidus*), Bridled Tern (*Onychoprion anaethetus*), and Magnificent Frigatebird (*Fregata magnifica*). In 2011 the national park became free of mammal IAS after a collaborative effort by GECI, CONANP, SEMARNAT, and the Mexican Navy, with funding from the National Fish and Wildlife Foundation. GECI successfully eradicated black rats from Pérez Island and house mice from Pájaros and Muertos Islands. Following the eradications, GECI continually visited the islands to monitor the recovery of the native fauna and to hold biosecurity workshops with the local community to strengthen coordination between park rangers and navy personnel. The collaboration also developed strategies for early detection of new incursions, with a focus on rodents.

Pérez Island is the most vulnerable of the archipelago because it is the only regularly visited island; it has permanent housing facilities for park managers, navy personnel, and researchers. In November 2015, the park manager received an alert about a potential rodent incursion on Pérez Island; a bar of soap located in one of the permanent housing facilities was found with bite marks. GECI immediately visited the island for a 2-week monitoring effort during which they found rat feces and additional chew marks in the same housing facility. In response GECI set 15 Tomahawk live traps and 15 Sherman traps inside and around the housing installations, and a 50 m × 50 m grid of wax chew blocks was set to cover the whole island. The rapid response effort totaled 300 trap nights and 400 block nights. On the first night the rat, a nonreproductive female, was captured inside a house. Morphometric measures were taken and tissue was collected for analysis. No further signs of rodent activity were reported. It was therefore concluded that the threat of rat establishment had been successfully removed.

Posteradication rodent monitoring continues on Arrecife Alacranes. Throughout the island GECI uses early detection devices known as rodent motels to assess the rodent-free condition of the island; GECI also visited the island chain twice in 2016 and confirmed the absence of rodents. Because local involvement has proven critical for the detection of IAS, outreach material developed and distributed by GECI has created a community that is more aware of the threats posed by IAS and how to prevent introductions.

Addressing the Reinvasion of Rats on the Bischof Islands, British Columbia

The Bischof Islands are a cluster of islets within Gwaii Haanas National Park Reserve, National Marine Conservation Area Reserve, and Haida Heritage Site in British Columbia. Primarily used for tourism, research, and fishing, Gwaii Haanas is jointly managed by the Council of the Haida Nation and the Parks Canada Agency. The national park reserve is within unceded Haida Nation territory and has been inhabited for more than 10,000 years. The Bischof Islands total approximately 0.85 km^2 and are 2.5 h by powerboat from the nearest present-day town on Haida Gwaii. Haida Gwaii is approximately 160 km from the mainland and is an archipelago consisting of over 150 islets just south of Alaska. The Bischof Islands currently include a Parks Canada float camp that acts as a research station for parks staff and a safe moorage for others who may use it when needed. There are foodstuffs, water, fuel, and operational supplies regularly transported between the town of Skidegate and the Bischof Islands, which results in an array of potential vectors through which IAS can be introduced.

In 2011 and 2012, Norway rats were successfully eradicated from the Bischof Islands using hand-baiting and bait stations (Parks Canada Agency and Coastal Conservation 2016) to protect important breeding habitat of seabirds, including colonies of the Ancient Murrelet (*Synthliboramphus antiquus*). In April 2013, however, managers discovered suspicious chew marks on brodifacoum bait blocks placed in standard Bell Labs Protecta black plastic bait stations on one of the islets in the island group. Due to inclement weather preventing access to the islet, confirmation of rodent presence was delayed until May 2013 when analyses of infrared camera images revealed rats chewing on fresh bait. Thereafter, bait stations and Tomahawk traps were deployed in May 2013. Genetic data from a live trap capture indicated that the rat was not from the population eradicated in 2012. It was therefore assumed that the rodent swam from a nearby rat-infested island, such as Lyell, or was introduced via vessel (Ashurst and Irvine 2016). Ongoing genetic work may further inform the routes of reinvasion and transport risk around the archipelago.

Several actions have been implemented since 2013 to reduce the reestablished rat population on the islands and to increase biosecurity awareness. A network of 36 Goodnature™ resetting rat traps were deployed in summer 2016 and were regularly rebaited and checked during the park reserve's operational season (April–October). A rat control and eradication action plan was drafted and many of the recommended actions have been carried out, such as prebaiting and trapping on all Parks Canada vessels for 2 weeks prior to the field season, boxing of all foodstuffs in rigid plastic, baiting and trapping within the field station throughout the winter and the operational season, and regular monitoring by infrared cameras. Furthermore, every visitor to Gwaii Haanas must participate in an orientation that includes information on the previously implemented rat eradications and the need for biosecurity; rat kits (including bait stations, stickers, and traps) are also offered to interested visitors (Gwaii Haanas 2016).

The reinvasion of rats on the Bischof Islands has provided managers with data that they can use to prevent future reintroductions. The incident emphasized the possibility of travel constraints and delayed response times during inclement weather, as well as the need to view images from remotely deployed cameras in real time. Thus managers should have a plan, resources, staff, and multiple detection and response tools in place at all times in case an IAS is detected during harsh weather conditions. In this example, it may have been helpful to have multiple types of bait on hand to increase bait uptake or to allow a helicopter bait drop.

FUTURE PRIORITIES

Although biosecurity programs vary widely, their development, implementation, and ability to adapt to changing global circumstances are vital in the line of defense against IAS threats to global biodiversity, especially on island ecosystems. A key first step is the development of a detailed, region-specific biosecurity plan that identifies the following: (1) the primary threats and pathways of IAS, (2) prevention activities, (3) detection tools and monitoring schemes, and (4) response plans and contingency actions. As demonstrated by the bottom-up strategy executed by GECI involving the local community throughout the planning process, a successful community biosecurity plan relies on the public's understanding and acceptance of the actions required to effectively implement the plan. This often involves modifying behaviors and changing the way that decisions are made, which can be a challenging task for adults who, over time, have developed personal beliefs and preconceived notions. Children are often more open to the introduction of novel concepts (Gopnik et al. 2015); thus, promoting children's understanding of and commitment to protecting native wildlife from IAS is an important goal of biodiversity conservation.

Island stakeholders should adaptively manage biosecurity programs by continually reviewing assessments of threats, introduction pathways, detection tools, and relative risks of incursions. Such assessments encourage managers to evaluate changing conditions and to identify potential or new threats. We recommend a consistent approach to the adaptive management process, such as using annual surveys or workshops to evaluate the scope and efficacy of the biosecurity program and to alter the biosecurity plan accordingly.

At times adaptive management may require justification to various stakeholders or—in the case of military islands such as Naval Auxiliary Landing Field San Clemente Island (SCL) and SNI—to commanding officers. Directives in biosecurity plans should strive to be exhaustive but also adaptable for and justifiable to stakeholders. Not all recommendations made within a biosecurity plan may be implementable, however, for reasons beyond the stakeholders' control or simply due to the cost of the program. Though it is nearly impossible to effectively calculate the cost of various biosecurity actions on even a local scale, the relative effort and values of the biosecurity strategy can be weighed against each other within a particular biosecurity plan holistically. Managers on SCL and SNI of the California Channel Islands are now justifying biosecurity actions by ranking and indexing the total effort level of each action; the "effort score" is defined by the effort of implementation, the number of personnel involved in the action, and the relative cost to enact that action. Additionally, the inherent value of the action is an important second component in prioritizing strategies by determining high-cost, low-value actions or low-cost, high-value actions that pertain to each island's biosecurity program. This second index ranks the strategic value of the biosecurity strategy on a scale of basic to advanced and is referred to as the "action value score."

The biosecurity effort score and the action value score are comprehensive when paired together and are intended to prioritize biosecurity strategies on a scale of easily implementable to a more intensive effort. Island managers can select strategies based on current management circumstances (e.g., taxa of concern and potential modes of transport) and available resources of their islands while adapting priorities on an on-going basis. We recommend that managers consider enacting a biosecurity effort index and action value tables to justify the effort, cost, and value of biosecurity, as well as to prioritize the numerous strategies available to island managers.

As governments across the globe increasingly fund expensive projects to eradicate IAS, it is necessary that a concurrent investment in biosecurity strategies occurs at a funding level sufficient to prevent new incursions. Biosecurity programs are designed to protect the investments made and to protect against new IAS invasions that may be infeasible to eradicate due to ecological, technological, or economic constraints. Demonstrating the value to both humans and the island ecosystem of a pest-free scenario using prevention methods and contrasting that with the cost of no action or a full eradication after an IAS introduction would allow funders to understand the importance of a proactive biosecurity program. The value to local island residents and visitors should be assessed in conjunction with the value to native species and ecosystem services. While it can be challenging to assign costs to the benefits associated with preventing IAS introductions, it should be a top priority for island managers to secure funds for biosecurity efforts. Potential reinvasions can be used to motivate investments in preventive measures because grant applications for eradications may be viewed with some skepticism after reinvasion threatens to eliminate the conservation gains of the original project.

Future global priorities should focus on strengthening insular biosecurity measures such as introduction prevention, island surveillance, and rapid response plans, including completing required permitting and compliance (Boser et al. in press). Future work should also develop genetic and technical tools to improve species-specific monitoring, detection, and eradication.

As demonstrated in New Zealand and other locations, the creation of local advisory groups is critical for providing thorough planning and response actions to biosecurity threats. We recommend the creation of a network of biosecurity experts that promotes regional and global collaboration through meetings and workshops. These workshops could be hosted on a rotating schedule by island managers in different regions to encourage diversity of participation. Such a network made up of individuals with specific skill sets can then be readily accessed in the case of a potential biosecurity threat, challenge, or need. Collaboration among the island community can increase efficiencies through the sharing of resources (e.g., staff and materials), facilitate the scaling up of biosecurity projects as funding sources are leveraged, and improve effectiveness by building upon the successes and failures of other programs.

Efforts such as the Trilateral Island Initiative and the Honolulu Challenge have created a framework for the global island community to collaborate on the conservation of islands (IUCN 2017, Trilateral Committee 2017). Through these initiatives, government agencies and organizations of different countries have identified and committed to shared goals and priorities, including biosecurity. The Island Biosecurity Working Group will promote these initiatives and partnerships in order to strengthen biosecurity programs at the local, national, and international scales.

Enhancing communication about island biosecurity on a global scale is a priority. Regular communication via listservs, annual meetings, and websites allows for the timely exchange of information. Relying on published papers often results in the delayed sharing of information which is largely focused on science rather than the practicality of project implementation. To address this, the Island Biosecurity Working Group has created an open-data internet library that contains content relevant to island biosecurity, such as biosecurity plans, best management practices, protocols, literature, lessons learned, outreach materials, and educational products (e.g., curricula). This portal can be found at http://www.californiaislands.net/biosecurity-plans/ and is used to promote collaboration and communication within the regional and global island community.

ACKNOWLEDGMENTS

We thank the 9th California Islands Symposium for hosting a session on biosecurity, from which the Island Biosecurity Working Group emerged. The biosecurity program for the Channel Islands is supported by Channel Islands National Park, the U.S. Navy, The Nature Conservancy, and the Catalina Island Conservancy. Pam Goodard from Thalassa Education was instrumental in the development of the Pribilof Islands seabird and invasive species curriculum. Thanks to Hernan Gonzalez Acosta from Servicio Agrícola y Ganadero Juan Fernández. Conservación de Islas thanks its partners CONABIO, CONANP, SEMARNAT and SCT, as well as the fishing cooperatives for their close collaboration in creating and implementing biosecurity measures for Mexico’s islands. Conservación de Islas also thanks the Global Environment Fund, United Nations Development Programme, and National Fish and Wildlife Foundation for their support. Thank you to John Knapp, William Hoyer, Martin Ruane, and Valerie Vartanian for their review of this paper.

Literature Cited

Aguirre-Muñoz, A., A.S. Herrera, L.L. Mendoza, A.O. Alcaraz, F.M. Sánchez, and J.H. Montoya. 2016. La restauración ambiental exitosa de las islas de Mexico: una reflexión sobre los avances a la fecha y los retos por venir. Pages 487–512 *in* E. Ceccon and C. Martinez-Garza, editors, Experiencias mexicanas en la restauración de los ecosistemas. 1st edition. Universidad Nacional Autónoma de México, Centro Regional de Investigaciones Multidisciplinarias; Universidad Autónoma del Estado de Morelos; Ciudad de México, Comisión Nacional para el Conocimiento y Uso de al Biodiversidad.

Aguirre- Muñoz, A., A. Samaniego-Herrera, L. Luna-Mendoza, A. Ortiz-Alcaraz, M. Rodriguez-Malagon, F. Mendez-Sanchez, and M. Latofski-Robles. 2011. Island restoration in Mexico: ecological outcomes after systematic eradications of invasive mammals. Island invasives: eradication and management. Proceedings of the International Conference on Island Invasives. IUCN, Gland, Switzerland; CBB, Auckland, New Zealand. xii + 542 pp.

Allan, D. 1985. Threatened 'protected natural areas' of the world. Environmental Conservation 12(1):76.

Ashurst, C., and R. Irvine. 2016. Summary of rat eradication attempts on Bischof Islands. Internal report, Parks Canada.

Bassett, I.E., J. Cook, F. Buchanan, and J.C. Russell. 2016. Treasure Islands: biosecurity in the Hauraki Gulf Marine Park. New Zealand Journal of Ecology 40(2):250–266.

Boser, C.L., C. Cory, K.R. Faulkner, J.M. Randall, J.J. Knapp, and S.A. Morrison. 2014. Strategies for biosecurity on a nearshore island in California. Monographs of the Western North American Naturalist 7:412–420.

Boser, C.L., P. Power, A. Little, J. Matos, G.R. Howald, J.M. Randall, and S.A. Morrison. In press. Proactive planning and compliance for High-Priority Invasive Species Rapid Response Programme. Proceedings of the International Conference on Island Invasives. IUCN, Gland, Switzerland.

Broome, K. 2007. Island biosecurity as a pest management tactic in New Zealand. Pages 104–106 *in* G.W. Witmer, W.C. Pitt, and K.A. Fagerstone, editors, Managing vertebrate invasive species: proceedings of an international symposium. USDA/APHIS Wildlife Services, National Wildlife Research Center, Fort Collins, CO.

Broome, K., and E. Kennedy. 2013. Action plan for improvements to island biosecurity. Internal report. DOC-1249639, Department of Conservation, New Zealand.

Brown, K., C. Giddy, K. Broome, and E. Murphy. 2012. Kapiti Island stoat incursion response report. Internal report. DOCDM-1024511, Department of Conservation, New Zealand.

Brown, K., D. Peters, and J. Mace. 2011. Kapiti Island stoat incursion response review. Internal report, DOCDM-803749, Department of Conservation, New Zealand.

[CBD] Convention on Biological Diversity. 2017. Aichi biodiversity targets. https://www.cbd.int/sp/targets

Cory, C., and J.J. Knapp. 2014. A program to eradicate twenty-four nonnative invasive plant species from Santa Cruz Island. Monographs of the Western North American Naturalist 7:455–464.

[DOC] Department of Conservation. 2017. New Zealand Biodiversity Action Plan 2016–2020. New Zealand.

Early, R., B.A. Bradley, J.S. Dukes, J.J. Lawler, J.D. Olden, D.M. Blumenthal, P. Gonzalez, E.D. Grosholz, I. Ibañez, L.P. Miller, and C.J. Sorte. 2016. Global threats from invasive alien species in the twenty-first century and national response capacities. Nature Communications 7:12485.

Environment Canada. 2004. An invasive alien species strategy for Canada. The Queen's Printer, Victoria, BC. 40 pp.

Funk, S.M., and J.E. Fa. 2010. Ecoregion prioritization suggests an armoury not a silver bullet for conservation planning. PLOS ONE 5(1):e8923.

Gopnik, A., T.L. Griffiths, and C.G. Lucas. 2015. When younger learners can be better (or at least more open-minded) than older ones. Current Directions in Psychological Science 24:87–92.

Gwaii Haanas. 2016. Gwaii Haanas Terrestrial Biosecurity Strategy. Unpublished document, Gwaii Haanas Archive.

Howald, G., C. Donlan, J.P. Galván, J.C. Russell, J. Parkes, A. Samaniego, Y. Wang, D. Veitch, P. Genovesi, M. Pascal, and A. Saunders. 2007. Invasive rodent eradication on islands. Conservation Biology 21:1258–1268.

[IUCN] International Union for Conservation of Nature. 2017. The Honolulu challenge on invasive alien species. https://www.iucn.org/theme/species/our-work/invasive-species/honolulu-challenge-invasive-alien-species

Junak, S., T. Ayers, R. Scott, D. Wilken, and D. Young. 1995. A flora of Santa Cruz Island. Santa Barbara Botanic Garden, Santa Barbara, CA; California Native Plant Society, Sacramento, CA. 397 pp.

Knapp, J., C. Cory, R. Wolstenholme, K. Walker, and B. Cohen. 2009. Santa Cruz Island invasive plant species map. Proceedings of the 7th California Islands Symposium. Institute for Wildlife Studies, Arcata, CA.

Loope, L.L., and D. Mueller-Dombois. 1989. Characteristics of invaded islands, with special reference to Hawaii. Pages 257–280 *in* J.A. Drake, H.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmanek, and M. Williamson, editors, Biological invasions: a global perspective. Published on behalf of the Scientific Committee on Problems of the Environment (SCOPE) of the International Council of Scientific Unions (ICSU). Wiley, Chichester, NY. 525 pp.

Lysnar, P. 2016. Summary of findings from Hauraki Gulf Treasure Islands campaign survey. Auckland Council, New Zealand.

Meek, P.D., G. Ballard, A. Claridge, R. Kays, K. Moseby, T. O'Brien, A. O'Connell, J. Sanderson, D.E. Swann, M. Tobler, and S. Townsend. 2014. Recommended guiding principles for reporting on camera trapping research. Biodiversity and Conservation 23:2321–2343.

Meek, P.D., and A. Pittet. 2014. A review of the ultimate camera trap for wildlife research and monitoring. Pages 101–110 *in* P. Meek, P. Fleming, G. Ballard, P. Banks, A. Claridge, J. Sanderson, and D. Swann, editors, Camera trapping: wildlife management and research. CSIRO Publishing, Collingwood, Australia.

[MPI] MINISTRY FOR PRIMARY INDUSTRIES. 2016. New Zealand's Biosecurity 2025 Direction Statement. New Zealand. https://www.mpi.govt.nz/protection-and-response/biosecurity/biosecurity-2025/biosecurity-2025/

NATIONAL ADVISORY COMMITTEE ON INVASIVE SPECIES. 2010. National strategy on invasive species in Mexico: prevention, control and eradication. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Comisión Nacional de Áreas Protegidas, Secretaría de Medio Ambiente y Recursos Naturales. México.

OUGH DEALY, H. AND E. GREIG. 2016. Dogs on pest-free island beaches in the Bay of Islands, Northland. Internal Report. DOC 2845381, Department of Conservation, New Zealand.

PARKS CANADA AGENCY AND COASTAL CONSERVATION 2016. Night birds returning: eradication of black rats (*Rattus rattus*) from Faraday and Murchison Islands. Internal project report. Gwaii Haanas National Park Reserve, National Marine Conservation Reserve and Haida Heritage Site, Skidegate, BC. 168 pp.

PEJCHAR, L., AND H.A. MOONEY. 2009. Invasive species, ecosystem services and human well-being. Trends in Ecology and Evolution 24:497–504.

PIMENTEL, D., S. MCNAIR, J. JANECKA, J. WIGHTMAN, C. SIMMONDS, C. O'CONNELL, E. WONG, L. RUSSEL, J. ZERN, T. AQUINO, AND T. TSOMONDO. 2001. Economic and environmental threats of alien plant, animal, and microbe invasions. Agriculture, Ecosystems and Environment 84:1–20.

RAMSEY, D.S.L., J.P. PARKES, D. WILL, C.C. HANSON, AND K.J. CAMPBELL. 2011. Quantifying the success of feral cat eradication, San Nicolas Island, California. New Zealand Journal of Ecology 35:163–173.

REASER, J.K., L.A. MEYERSON, Q. CRONK, M. DE POORTER, L.G. ELDREGE, E. GREEN, AND L. VAIUTU. 2007. Ecological and socioeconomic impacts of invasive alien species in island ecosystems. Environmental Conservation 34:98–111.

RUSSELL, J.C., D.R. TOWNS, AND M.N. CLOUT. 2008. Review of rat invasion biology: implications for island biosecurity. Science for Conservation 286, Department of Conservation, Wellington, New Zealand. 53 pp.

SAX, D.F., AND S.D. GAINES. 2008. Species invasions and extinction: the future of native biodiversity on islands. Proceedings of the National Academy of Sciences 105 (Supplement 1):11490–11497.

STOHLGREN, T.J., AND J.L. SCHNASE. 2006. Risk analysis for biological hazards: what we need to know about invasive species. Risk Analysis 26:163–173.

[TRILATERAL COMMITTEE] TRILATERAL COMMITTEE FOR WILDLIFE AND ECOSYSTEM CONSERVATION AND MANAGEMENT. 2017. Trilateral Island Initiative. http://trilat.org

VALDEBENITO, H., T.F. STUESSY, D.J. CRAWFORD, AND M. SILVA. 1992. Evolution of Erigeron (Compositae) in the Juan Fernandez Islands, Chile. Systematic Botany 17:470–480.

VITOUSEK, P.M., C.M. D'ANTONIO, L.L. LOOPE, AND R. WESTBROOKS. 1996. Biological invasions as global environmental change. American Scientist 84: 468–478.

WILDLANDS CONSERVATION SCIENCE. 2015. NCHI_Heli Surv 2015 file geodatabase. NCHI_FinalDeliv_2015 feature data set. Unpublished data provided to The Nature Conservancy.

WILLIAMS, M.J., AND B. BASSE. 2006. Indigenous grey ducks *Anas superciliosa* and introduced mallards *A. platyrhynchos* in New Zealand: processes and outcome of a deliberate meeting. *In:* R. Schodde, editor, Proceedings of the 23rd International Ornithological Congress. Acta Zoologica Sinica 52(Supplement):579–582.

Received 28 February 2017
Revised 6 December 2017
Accepted 19 December 2017
Published online 29 October 2018