Improvement of a kill trap for mongoose eradication projects on two islands in Japan

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The small Indian mongoose (*Herpestes javanicus*) was established on Okinawa Island (1206km^2) in 1910 and on Amami-oshima Island (712 km^2) in 1979. In 2000, national and prefectural governments launched a mongoose control project on both islands. In 2005, the Invasive Alien Species Act was enforced in Japan and a ten year eradication programme launched. By 2009, this eradication project was in its fifth year. Adequate trapping is important but live trapping techniques are too labour intensive to use over large areas. We began using kill traps in 2003 on Amami and 2008 on Okinawa and gradually increased their numbers. However, a species of endemic bird and two species of rat were captured as non-target species so the traps have had to be repeatedly improved. The two native rat species, which inhabit Amami and Okinawa, are also affected by mongoose introduction and their distribution range is reducing in the areas where mongoose are abundant. Remodeled kill-traps enable us to avoid unintentionally catching native birds, but it is difficult to avoid catching the rats. Therefore kill-traps and live traps were used separately depending on the areas and the seasons when rats were active. Now that mongoose density has decreased to low levels, some native animals including rats are recovering. While the native rats recover, the trapping area where we can use kill-traps is declining. We now need additional improvements to trap design, or good lures for the mongoose, in order to avoid detrimental effects on native rats.

Potential operational evolution in pest eradication through use of a self-resetting trap

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Eradication and management of stoats *(Mustela erminea)* and rats *(Rattus rattus* and *R. norvegicus)* is of vital importance to biosecurity in New Zealand. Kill trap operations have proved the ability to eradicate and control populations sufficient for the protection of native species but require intensive and continued maintenance and expense. Goodnature Limited and the Department of Conservation collaborated to develop a self resetting trap for stoats and rats to exceed the annual performance of current trap schedules with no human intervention, be lightweight, durable and user friendly. Development and testing was completed in June 2009 resulting in a new control tool which kills, clears and resets twelve times before requiring human intervention. This development allows entire control networks to achieve a 'knockdown period' and then remain 100% available to pest predators, dramatically reducing labour required in operation set up and maintenance. It is speculated that this tool will lead to new operational strategies allowing eradication and management of rats and stoats in significantly larger areas.

Multi-threat control strategies for endangered species management on O'ahu army lands in Hawai'i

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The U.S. Army Garrison Hawai'i is required to manage 67 endangered taxa, including 51 plants, nine tree snails, one bird species, and potentially six picturewing flies on the island of O'ahu, Hawai'i. These species occupy fragmented, disturbed habitat and face multiple threats. The O'ahu Army Natural Resources Program (OANRP) manages these species across 56 geographically defined Management Units (MUs). Located on the rim of Makua Valley, the Kahanahāiki MU encompasses 36.4 ha (90 acres) of mixed native/invasive mesic forest and is home to one tree snail species and both wild and reintroduced populations of 10 endangered plant taxa, including *Cyanea superba* ssp. *superba*, which was extirpated from the wild in 2003. Threats include feral pigs (*Sus scrofa*), ship rats (*Rattus rattus*) and Pacific rats (*R. exulans*), mice (*Mus musculus*), weeds, snails, slugs, and arthropods. The goal of threat control is to restore habitat in the MU such that endangered taxa thrive and maintain viable, stable populations. Multiple threats must be controlled simultaneously to achieve this goal. Feral ungulates were successfully excluded from the area in 1997 via fencing and snaring. A large snap trap grid, installed in early 2009, maintains low numbers of rodents. Weeds are primarily managed around rare taxa, although more aggressive restoration projects seek to create more continuous native forest. Both incipient and established weeds are controlled. Invasive slugs, predators of native seedlings, are controlled using a natural product containing iron phosphate. Native tree snails are protected from the carnivorous snail *Euglandina rosea* via multiple barrier (salt, electricity, overhang) exclosures. Experiments to detect *E. rosea* using dogs are ongoing. Ant surveys allowed for the detection and eradication of an incipient population of *Solenopsis geminata*. Black twig borer (*Xylosandrus compactus*) traps are deployed around endangered trees. Rare taxa are responding to these efforts; in 2009, wild seedlings of *C. superba* were documented for the first time in over 30 years.

Island restoration on the Faraday-Ramsay Island group in Gwaii Haanas National Park Reserve and Haida Heritage Site, Haida Gwaii, Canada

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Gwaii Haanas National Park Reserve and Haida Heritage Site is a large protected area jointly managed by the Council of the Haida Nation and Parks Canada Agency. It is located in the southern region of Haida Gwaii, a remote off-shore archipelago of over 150 islands (~1 million hectares) in the Pacific Northwest of Canada. The Gwaii Haanas management plan and State of the Protected Area reports identify introduced species of deer, elk (*Cervus canadensis*), rats (*Rattus* spp.), beavers (*Castor canadensis*), muskrats (*Ondatra zibethicus*), raccoons (*Procyon lotor*), red squirrels (*Tamiasciurus hudsonicus*), house mice (*Mus musculus*), amphibians, birds and many species of invasive plants as the biggest threat to the ecological integrity of Gwaii Haanas. Many introduced species in Gwaii Haanas are widespread throughout the archipelago; however, some island groups have been less impacted because of their relative isolation and limited human use history. Under our mandate to protect and present examples of our natural heritage, the priority to restore these islands is high. In the island group extending from Faraday Island to Ramsay Island, the only species of introduced vertebrates are ship rats (*Rattus rattus*), Norway rats (*R. norvegicus*), and sitka black-tailed deer (*Odocoileus hemionus sitkensis*) in addition to an unknown number of introduced plants occurring at low density along island margins; it is thus an excellent candidate for complete eradication of introduced species. Our Night Birds Returning project endeavours to eradicate introduced rats from seabird nesting islands in this group, while exploring the long-term ecosystem impacts of rat removal, including both direct and indirect impacts to the terrestrial and intertidal areas surrounding these islands. Building on the work of other successful projects, this work is proposed in two stages, starting with a smaller chain of islands (100 ha) to build capacity and community support. Long term plans are under consideration to target deer removal, but logistical difficulties present many challenges. A small scale experimental project to eradicate one invasive plant species is underway, while a larger framework to guide the control and eradication of all introduced plants is being developed.

Population level impacts of localised ferret control: storing up problems for the future?

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Eradication of introduced mammalian predators is not always an immediately feasible option because of logistical, financial and social constraints. Thus, in many cases, lethal control is carried out only around key sites, often with little study of the population level impacts on the controlled species. We studied the behavioural ecology and population dynamics of feral ferrets (*Mustela furo*) on Rathlin Island, UK both pre- and post-control, to examine the effects on the entire island population. Prior to control, over-winter ferret densities were relatively low but animals maintained large home range overlaps and were often found in close association with other individuals. Control was then carried out in limited blocks to mimic protection of important areas for breeding ground-nesting birds. This was highly effective in reducing ferret numbers, with no immigration detected prior to juvenile dispersal. However, the population was found to have substantially increased in the winter following control, remaining high throughout, facilitated by the lack of territoriality. Our study thus suggests limited removal may be counter-productive, and demonstrates how apparently effective control can actually exacerbate the situation in subsequent seasons. This paradox merits further consideration as it may also act for other flexible species, particularly if defining resources such as shelter or food are not limiting.

The Pacific Invasives Initiative Resource Kit for planning rodent and cat eradication projects

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Successful removal of invasive species, such as rodents and cats, from islands requires comprehensive planning. Through its extensive capacity building work with project partners in the Pacific, the Pacific Invasives Initiative (PII) has identified the need for information resources to assist Pacific practitioners in carrying out their invasive species eradication projects. Currently, project managers often do not know where to access relevant information and/or gather information from a variety of sources which can be very time consuming. In response to this, PII has produced a Resource Kit for Planning Rodent and Cat Eradication Projects. The resource kit acts as a "one stop shop" and comprises the PII Development and Implementation Planning Process and all essential supporting tools. The resource kit provides access to a range of information sources including current knowledge and best practice. While the focus of the resource kit is the islands of the Pacific, many of the tools can be readily adapted to other island projects, making it a global capacity building tool. This paper describes the Planning Process and how the resource kit tools will be used to increase the effectiveness of invasive species eradication projects.

The Island Eradication Advisory Group (IEAG) – A model of effective technical support for eradication project planning and management

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The IEAG is a small group of New Zealand Department of Conservation (DOC) staff who represent the best island eradication experience available within DOC. Set up in 1997 to capture existing knowledge and expertise and provide technical advice to up-and-coming DOC projects, the role has diversified into six key areas. These are technical support for eradication projects and island biosecurity; evaluation of best practice for pest eradication; building capability within DOC for pest eradication work; advice on national priorities for island eradication projects; and international networking to maintain DOC's knowledge base by participating in the exploration and resolution of island eradication issues worldwide. Key elements to the success of the group are: a strong customer focus to meet the needs of the project manager; clear separation between advice and decision-making; a team approach to each project; and effective communication. The group meets three times a year and these meetings involve discussion and problem solving with project managers which are then followed up by written advice agreed at the meeting. The IEAG will respond to requests for advice at any time to meet the needs of project managers. Individual members contribute to group discussions via email or conference call to provide a collective view. Many projects have the IEAG undertake pre-operational 'readiness checks' to identify outstanding issues that need to be addressed before implementation. Examples of projects involving IEAG are presented. Key elements in the success of IEAG advice are: robust debate and review involving the IEAG and the project managers; making the most of collective knowledge; challenging assumptions and growing project managers' experience. We think this approach can be adapted to be useful in other parts of the world.

Disperser communities and legacies of goat grazing determine forest succession on the remote Three Kings Islands, New Zealand

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Many remote islands are degraded as a result of deforestation and browsing of vegetation by introduced goats. Goat (*Capra hircus*) eradication is therefore a focus for island restoration but there are few long-term records of changes to islands after eradications. Goats were eradicated from Great Island (Manawa Tawhi), 60 km from the northern tip of New Zealand, in 1946. Three permanent vegetation study plots were established on the island, across a sequence of forest succession, immediately after goat eradication and provide a 57-year record of change. Over the first 17 years, tree diversity in plots increased due to the recruitment of palatable trees. Over the next 40 years, diversity remained similar and forests have been less dynamic. Unpalatable understorey sedges, present when goats were abundant, have persisted and may be impeding tree seedling establishment. Most woody plant species on the island are bird-dispersed. Non-native *Turdus* species are probably important dispersers of many of the small-seeded species. Large-seeded species were unable to germinate away from parents until the native pigeon (*Hemiphaga novaeseelandiae*) were established on the island during the last decade. The slow rate of succession after goat eradication and the current low-diversity forests, compared with the available species pool, reflect legacies of past deforestation, communities induced by goat grazing, and the limited capacity of the resident bird species to disperse many of the potential canopy trees. Our results indicate that restoration of remote islands could require manipulation of goat-induced vegetation or may require sufficient time for favourable habitat for keystone dispersers to develop.

Of rats and birds: creating a seabirds' paradise on Dog Island, Anguilla

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Invasive species are known to cause severe impacts on island ecosystems. One such invasive known to have deleterious effects on islands is the ship rat (*Rattus rattus*). These rats are a potential threat to seabirds. Live traps were utilised to conduct a feasibility study to ascertain the presence of rats on Dog Island, Anguilla, which hosts eight species of seabirds, including one of the Caribbean's largest nesting populations of sooty terns (*Sterna fuscata*) (170,000 pairs). The results indicated that though the ship rat population is relatively high, it should be technically possible to eradicate them from the island using brodifacoum bait and ground-based rat eradication techniques, both of which have been successfully used on other islands. It is anticipated the eradication of ship rats will be achieved within thirteen weeks of the commencement of the programme. It is also expected that the eradication of rats on Dog Island will enhance the island's seabird populations as well as its biodiversity in general.

Developing national eradication capacity for the restoration of globally important seabird islands in the Pacific

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The Pacific island archipelagos of French Polynesia, New Caledonia, Palau, and Fiji support a diverse seabird fauna but, many species and breeding colonies are threatened as a result of the introduction of mammalian predators. Several of these island seabird colonies are globally Important Bird Areas (IBAs) and priorities for conservation. As such, BirdLife International and national non-government conservation organisations in French Polynesia, New Caledonia, Palau, and Fiji implemented a regional island restoration programme between 2007 and 2009 with the aim of eradicating rats from seabird IBAs. How this programme has lead to the development of eradication capacity in four countries, resulting in the completion of rat eradication operations for 16 islands of global importance for seabirds, is discussed, as are the initial results and future restoration priorities and capacity needs.

Toxins, baits and delivery systems for island use

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While there are issues with the repeat use of baits containing brodifacoum in the environment, one-off use for eradication of rodents can result in benefits that significantly outweigh non-target effects. This has been a recommended use pattern for more than 100 islands around the coast of NZ which have been cleared of introduced unwanted rats (*Rattus* spp.) and mice (*Mus musculus*). Nevertheless, difficulties with the existing baits provide a stimulus to search for baits that more effectively target mice as well as rats for island eradication. While alternatives to brodifacoum are seen as more important for enabling effective sustained control, they may, in some situations, still have potential benefits for pest eradication on islands. Current product development is focused on extending the utility of existing "low residue" toxins such as zinc phosphide, cholecalciferol and a combination of coumatetralyl and cholecalciferol in baits that are particularly palatable to rats and mice. We are also pursuing the registration of products containing substances such as sodium nitrite and para-aminopropiophenone (PAPP) and are working on baits and delivery systems to improve target specificity. Our work with PAPP for stoat (*Mustela erminea*) and cat (*Felis catus*) control in NZ provides a platform to search for a novel class of rodenticides but this will take a few years to complete. In the short term diphacinone, cholecalciferol and low dose cholecalciferol in combination with coumatetralyl represent low risk acute toxins for control of rats and mice without secondary poisoning. Research focusing on the registration of new solid multispecies baits should yield registered alternative rodenticide baits suitable for aerial application.

Estimating spatio-temporal change in population size of an invasive species from capture records: application for the mongoose eradication project on Amami Island, Japan

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Estimation of the effect of the control and the spatio-temporal change in the population size of an invasive alien species helps to evaluate and improve the strategy for the eradication. It is necessary to establish models to estimate the population dynamics of an invasive alien species from the information obtained in the eradication process. On Amami Island, Japan, small Asian mongoose (*Herpestes javanicus*) was introduced as a biological control agent for the native poisonous snake, habu (*Protobothrops flavoviridis*), in 1979. The predation of the non-target endemic animals by the mongoose has been a great threat of the biodiversity conservation. In 2000, the Ministry of Environment began an eradication project against mongoose. The removal of the mongoose has been done using traps, and the location and capture history of almost all the traps have been recorded. In this study, we established a hierarchical model to estimate the efficiency of capture and the spatio-temporal change in the population size from the capture history. Our model consists of the population dynamics and the relationship of the population size and the trapping effort to the number of capture. Our model allows the spatio-temporal heterogeneity in the population growth rate. Using Markov Chain Monte Carlo (MCMC) method, the population size and its growth rate in each time and place and the capture probability of the trap were estimated from the data of the number of captured mongoose and the trapping effort. We also suggested the index of the optimal spatial arrangement of traps from the estimated values. The data used in this study was obtained by Amami Mongoose Eradication Project by Naha Nature Conservation Office, Ministry of the Environment, Japan. Trapping and the recording of captures have been done by Amami Mongoose Busters.

The origin of amphibian chytridiomycosis: did it come from Japan?

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A serious disease of amphibians caused by the chytrid fungus *Batrachochytrium dendrobatidis* was first discovered in Japan in December 2006 in imported pet frogs. This was the first report of chytridiomycosis in Asia. To inspect the origin and expansion process of the chytrid fungus in Japan, we surveyed the distribution and genetic variation of the fungus among captive and wild frog populations. We established a nested PCR assay that uses two pairs of PCR primers to amplify the internal transcribed spacer (ITS) region of a ribosomal RNA cassette to detect mild fungal infections from as little as 0.001 pg (1 fg) of *B. dendrobatidis* DNA. We collected swab samples from 559 captive amphibians, and 5565 wild amphibians collected at field sites from northern to southwestern Japan. We detected infections in native and exotic species, both in captivity and in the field. Sequencing of PCR products revealed 50 haplotypes of the *B. dendrobatidis* ITS region. Phylogenetic analysis for the haplotypes combined with haplotype sequences already detected in other countries showed that genetic diversity of *Bd* in Japan was higher than that in other countries. Furthermore, it was suggested that three of the haplotypes detected in Japan were specific to the Japanese giant salamander (*Andrias japonicus*) and appeared to have established a commensal relationship with this native amphibian. The highest genetic diversity of *B. dendrobatidis* was found in the sword-tail newt (*Cynops ensicauda*), endemic to Okinawa Islands and the next highest in the alien American bullfrog (*Rana catesbeiana*). From these results, combined with no evidence of chytridiomycosis occurrence in the Japanese native species, we came to a new hypothesis for the source of the fungus: “Asia or Japan origin hypothesis”. To improve chytridiomycosis risk management in the world, we must restrict the amphibian trade, especially from Japan.

Establishing the raccoon control system and its issues in Hokkaido, Japan

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Pet raccoons (*Procyon lotor*) that have been abandoned or escaped have become established in Japan and are extending their range, damaging agriculture nationwide and substantially impacting on the native ecosystem. In Hokkaido, scientists and governments have been addressing this issue together. Initially, raccoons were captured as part of harmful wildlife control; however, this approach lacked evaluation of the captures. Consequently, to contribute to consensus building for the control system, target capture numbers were determined by predicting population dynamics scientifically with reproduction data analysis of captured individuals. We set model areas and verified the efficacy of the capture by continuing the same capture approach. As a result, it was shown that population density can be kept at, or below, two animals/km^2 solely by placing cage traps every 500 m in the area and conducting three continuous weeks of capture once a year. Also, as there was a correlation between the population density and the capture per unit effort (CPUE), CPUE was introduced as a relative index of population density. At present, local governments aim to reduce CPUE to 1 animal/100 trap nights, corresponding approximately to a population density of 1 animal/km^2. However, the current capturing method using cage traps is not cost effective in low population density areas. Thus, development of effective capturing approaches in such areas, including training of raccoon detective dogs, is a challenge. Furthermore, although Japan is deeply concerned about the impact of alien species on the population, it remains relatively unaware of their impact on the native ecosystem. Japanese people have a strong reluctance to kill animals and, therefore, public awareness-raising is also required, as well as the reinforcement of social education regarding invasive alien species.

The invasion of the Argentine ant across continents, and their eradication

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The Argentine ant (*Linepithema humile*) has successfully spread from its native range in South America across much of the globe. This species is highly polygynous and possesses a social structure, called ‘supercolony’ whereby individuals mix freely among separated nests. The introduced populations of the Argentine ant are characterised by the formation of very large supercolonies across thousands of kilometres, whereas colony size is generally smaller in the native ranges. Gene flow among supercolonies has been considered to be very limited or even absent. The Argentine ant, first noted in 1993, is now found in several regions of Japan. Early detection, as well as rapid control, is required to prevent further expansion of the species. A vital component of this prevention is the identification of pathways of introduction into new locations. First, we attempted to demonstrate the genetic structure of the Argentine ant to understand its dispersal history. Sequencing of the mitochondrial DNA from the Japanese and overseas populations showed that one haplotype is shared among different populations distributed in USA, Europe, Australia, and Japan. Three haplotypes were shared among four supercolonies with high levels of aggression in Japan. These results indicate that one massive supercolony is distributed across the continent and that replicated introductions may occur in Japan. Secondly, for understanding the mechanism of formation of the massive supercolony we examined whether gene flow can occur among supercolonies. As a result of investigations of reproductive schedules and aggression of workers toward males, gene flow may be limited between adjacent supercolonies. Finally, we introduce the eradication trials of the Argentine ant in Japan.

Mongoose, rat and acorn - forest dynamics and ecosystem management on Amami Island, Japan

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The small Indian mongoose (*Hepestes javanicus*) has been spreading on Amami Island for 30 years. The island is at the north-eastern most corner of the Oriental region, and is rich in endemic species of subtropical forest. In the last decade, there has been intensive control of mongoose by the Ministry of the Environment. Mongoose are at low density and distribution covers up to 300 square kilometres over a complex forest ecosystem with complicated terrain. The island hosts another invasive alien mammal, ship rat (*Rattus rattus*), which greatly increases in abundance in forest after the rich acorn crops of the ever-green oak (*Castanopsis sieboldii*), an extremely widespread tree. Ship rats and a wintering thrush (*Turdus pallidus*) are two important winter foods for mongoose. Reproduction, dispersal, and also trapping performance of mongoose should depend on the abundance of rats, the thrush and other animals, which also fluctuate with acorn production. Understanding the patterns and process of the food web through acorns, rats, other native animals, and mongoose helps with developing optimal control strategies (lowest cost and highest benefit) and to investigate the possibility of mongoose eradication. Ecosystem management thinking is thus indispensable for invasive species control on Amami Island.

Eradication of exotic rodents off six high conservation value Western Australian islands

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Introduced rodents are a major threat to the biodiversity of islands around the world, including Australia. In 2009, a Threat Abatement Plan to reduce the impacts of exotic rodents on biodiversity on Australian offshore islands of less than 100,000 hectares was approved by the Commonwealth Government. Introduced rodents are known from at least 69 islands off the Western Australia coast and since the 1980s successful eradication programmes have been implemented on half of these. This project will eradicate introduced house mice (*Mus musculus*) and rats (*Rattus* spp) from another six high conservation value islands over a four year period. House mice will be eradicated from Three Bays and Faure islands in Shark Bay; ship rats (*R. rattus*) from Sunday and Long in the Kimberley and Direction Island in the Cocos-Keeling group; and Pacific rats (*R. exulans*) from Adele Island also off the Kimberley coast. In addition, a survey of Dirk Hartog Island in the Shark Bay World Heritage Area will be undertaken to confirm or otherwise, the presence of ship rats on this 68,000 ha island. Where bait spreading by helicopter is not practical and where non-target issues are present, appropriate bait stations will be developed and deployed. Where bait stations can not be developed to prevent access to baits by non-target species, some may be removed from the island, eradication undertaken and the non-targets returned once eradication has been confirmed. Eradication will most likely be by baiting with the anticoagulant poison, brodifacoum; however, there have been recent developments with other baiting formulations and these will be utilised if appropriate. The eradication programmes will be supported by short and longer term monitoring programmes, an education programme and quarantine protocols will be developed to ensure islands remain free of introduced rodents. Indigenous communities will be engaged to assist with eradication and monitoring activities.

Effectiveness of bait tubes for brown treesnake control on Guam

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A bait tube is a device with which a toxicant inserted in a dead mouse (*Mus musculus*) can be delivered to invasive brown treesnakes (*Boiga irregularis*) with low risk of non-target bait take. We tested two bait tube designs in a 5ha snake enclosure where the identity of virtually every snake is known. Instead of using toxicants, we implanted radio transmitters in small (6.6±1.4 g) and large (21.8±2.9 g) bait mice. Knowing all snakes present in the population allowed us to characterize not only covariates of snakes taking bait, but also those of snakes evading our mock control effort, and if snake covariates interacted with any design variable in determining targeting rate. Tube design had no effect on take rate. Snake snout-vent length was a strong predictor of success: none of the 29 snakes smaller than 843 mm took any bait, while the 126 snakes ≥843 mm were responsible for a total of 164 bait takes. The smallest of these snakes were able to ingest small and large mice, but tended to consume small bait at a higher rate than large bait. The main reason for our failure to target smallest snakes appears not to be gape limitation, but rather that small snakes prefer other prey (lizards). The time it takes a snake to grow from the size threshold observed to the size of maturation has implications for the interval between discrete efforts using toxic bait. Targeting all snakes before reproduction can occur is highly desirable; otherwise, a new cohort of refractory snakes may enter the population.

Economics of biocontrol for management of *Miconia calvescens*

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Ecological devastation in Tahiti and the threat to biodiversity and watersheds in Hawaii has deemed *Miconia calvescens* a priority invasive plant. Since the early 1990s, millions of dollars have been spent on advanced technologies and best management practices to reduce the prevalence and spread of the tree. On the islands of Hawaii and Maui, aerial reconnaissance and GIS are used to monitor and map populations; manual removal and herbicide treatments are used to destroy the plants. Long term suppression of *Miconia* remains at bay, and years of effort is being continually threatened by rising costs and uncertain budgets. To this end, scientists in Hawaii have been collecting and testing biological control agents for their effectiveness and host specificity. Using information from Hawaii tests of a stem weevil *Cryptorhynchus melastomae* and a nematode *Ditylenchus gallaeformis*, we simulated release scenarios; estimated the total cost of research, development, release, and monitoring; and compared biocontrol costs to projected expenditures under current best management practices. We estimated that net benefits from biocontrol agent release on a *single* Hawaiian island could reach US$10 million in 50 years. These results strongly indicate that continued research for a safe and effective biocontrol agent in Hawaii is economically warranted.

Eradicating foxes from Phillip Island, Victoria: techniques used and ecological implications

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The red fox (*Vulpes vulpes*) is considered to be the greatest land-based threat to little penguins (*Eudyptula minor*) on Phillip Island, in Victoria, Australia. Phillip Island Nature Parks has commissioned a fox eradication strategy to manage the threat and is committed to eradicating foxes from Phillip Island within five years. Island-wide 1080 baiting on private and public land has been employed as the most efficient method for broad-scale control and is supplemented by other methods, such as trapping, spotlighting and den fumigation. The use of scent dogs to detect fox scats is seen to be instrumental in locating and destroying the last few individual foxes on Phillip Island. As foxes are a cryptic species, monitoring fox abundance is difficult. Deriving relative abundance indices from a number of different parameters influenced by fox presence is considered the best way to assess success of the eradication programme. The number of penguins killed by foxes has fallen to extremely low levels (two penguins in 2008/2009 from over 300 penguins in previous years) and other key indicator species such as Cape Barren geese (*Cereopsis novaehollandiae*) and masked lapwings (*Vanellus miles*) are showing signs of population increases. Comparing bait take, spotlight transects and efficiency or catch per unit effort (CPUE) of each method over time is another method to gauge the success of the programme. Another result of the eradication programme has been an increase in mesopredators such as feral cats due to reduced competition and direct predation from foxes. Nature Park staff destroyed over 130 feral cats from farmland and reserves on Phillip Island last year and are now undertaking a public education campaign to educate the community on responsible cat ownership and the threat cats pose to native wildlife.

Goat eradication on Kangaroo Island, South Australia

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The high conservation value of Kangaroo Island has prompted the KI Natural Resources Management Board, in association with the Invasive Animals Cooperative Research Centre and South Australian Government, to implement a feral animal control programme targeting a number of species. Eradication of goats (*Capra hircus*) is one of the most successful components of the programme. Goats arrived with the first settlers to Kangaroo Island nearly 200 years ago and over the years the western and northern coastal environments have become population strongholds. Goats were controlled by opportunistic ground shooting until a coordinated strategic approach was set in place in 2006. Public meetings and discussions with the community helped identify the area of the island populated by feral goats. That area was divided into seven management units (MUs) using natural barriers as boundaries to help systematic eradication, one MU at a time, and limit re-infestations. Sterilised goats fitted with radio-telemetry collars (Judas goats) were first released into the first three MUs to join feral populations and determine effectiveness in this environment. Over the past three years, the 27 Judas goats released have provided information on movements, including the location of watering points and shelter locations, group size and behaviour in specific areas. Because of the Judas goats, 997 feral goats have been easily found and destroyed with little extra effort required for the last few. Four management units are now in a monitoring stage with no feral goats spotted for over a year. The remaining three management units are currently being targeted and eradication should be complete by 2012. The success of the programme is attributed to the well-planned approach, effective destruction techniques implemented by skilled staff, and the support and participation of all stakeholders.

Eradication of non-native tilapia from a natural crater lake in the Galapagos Archipelago, Ecuador

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In 2006, Nile tilapia (*Oreochromis niloticus*) were discovered in Laguna El Junco, a natural crater lake on Isla San Cristobal, Galapagos Archipelago, Ecuador. The largest body of freshwater in the Galapagos, El Junco was naturally devoid of fishes. Galapagos National Park, in conjunction with the Charles Darwin Foundation, drafted a plan in 2006 proposing application of rotenone, a commonly used fish poison, to eradicate the tilapia. In August 2007, we visited the lake and surveyed surrounding areas. We verified the identity of the fish, confirmed that the lake population was reproducing, and concluded the tilapia were likely restricted to the lake. Eradication was justified because predation by tilapia was changing the composition and abundance of the lake's native invertebrate community, negatively affecting some species considered endemic to the Galapagos. Moreover, the longer the tilapia persisted, the greater the likelihood of dispersal into other aquatic habitats. We conducted a series of toxicological tests on tilapia and invertebrates from El Junco to determine the optimal concentrations of rotenone to apply. We also sampled aquatic invertebrates from the lake, reserving some in refuge tanks for later restocking. Following months of planning, on 25 January 2008 liquid rotenone was applied and over the next few days approximately 40,000 dead and dying tilapia were removed from the lake. After tilapia removal, and once all residual rotenone in the lake had degraded sufficiently, captive invertebrates were released back into El Junco to speed recovery of invertebrate communities. No live tilapia have been collected or observed since 31 January 2008.

A newly recorded alien population of a lizard *Plestiodon japonicus* in Hachijojima Island, central Japan

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The scincid lizard *Plestiodon japonicus* is naturally distributed in part of the Japanese main islands and the coastal region of eastern Russia. Since the spring of 2004, an alien population of this species has been recorded in Hachijojima Island, central Japan, where a congeneric population of *P. latiscutatus* is naturally distributed. As native lizard populations are already facing extinction from an alien predator (the Japanese weasel (*Mustela itatsi*)), the alien lizard population will elevate the extinction risk of the native species through competition and introgressive hybridisation. Our preliminary study in 2007 and 2008 suggested the following: the alien species has already established a breeding population; the alien population was localised in a small part of the island and did not occur alongside the native congener; the alien population had slight genetic variation and therefore seemed to originate from a single source; little or no hybridisation with the native congener occurred. The invasion of the alien population may be at an early stage and therefore prompt eradication will suppress the impacts of the alien lizard.

Context matters: assessing the biodiversity benefits of pest eradication

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The biodiversity benefit obtained from the eradication of a particular pest on a particular island depends on both the biodiversity context around the island, as well as the pest context (e.g., suite of pests) on the island. The biodiversity benefits of pest eradication on an island depend on the archipelagic biodiversity context, including the rarity of the native species on the island, whether they are present on other islands, and whether they are being managed on other islands. Well-known concepts from conservation planning, such as complementarity and irreplaceability, can be used to illustrate the importance of archipelagic biodiversity context in choosing what pests to eradicate on which islands. Pest context matters also; the marginal benefits of removing a particular pest depends not only on the effects of that pest on the native species, but also on what other pests are on the island, and their effects on native species. I illustrate both of these contextual effects, using the Vital Sites model, which contains spatially explicit information on the New Zealand distributions of native species and pests, and simple models of the impacts of pests on native species. The removal of a particular pest provides more biodiversity benefit if it is the last pest removed from the island, than if it is the first pest removed from the island. This result is independent from, and exacerbated by, increases in the density of remaining pests due to reduced competition or predation from the removed pest. Furthermore, the marginal operational costs of controlling a particular pest are likely to decrease, as more pests are controlled. Both of these effects argue for multiple (rather than single) pest eradications. These results have important consequences for deciding what pests to eradicate or control on which islands, and whether to do single or multiple eradications.

Control of the invasive ship rat (*Rattus rattus*) and Pacific rat (*Rattus exulans*) using a large scale trapping grid for endangered tree snail and plant conservation in Hawaii

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Introduced rats (*Rattus* sp.) in Hawaii are known predators of birds, tree snails, and plants. Since 1997, the Oahu Army Natural Resources Program has been controlling rats through the use of diphacinone rodenticide in bait stations and snap traps on a relatively small scale at multiple sites for the protection of the endangered Oahu elepaio (*Chasempis sandwichensis ibidis*), five endangered Oahu tree snail species (*Achatinella* sp.), and seven endangered plants species. In May 2009, rat control was initiated over a 26 ha forested management unit with 400 snap traps on the island of Oahu. The New Zealand Department of Conservation current best practice rat trap technology is being utilised for the first time in Hawaii with this trapping effort. Rat activity within the management unit will be monitored through the use of tracking tunnels. Forest health, the endangered plant *Cyanea superba* subsp. *superba*, the Oahu tree snail *Achatinella mustelina*, and native invertebrates will be monitored closely to determine the effectiveness of the methodology. Introduced slugs and the predator snail *Euglandia rosea* will also be monitored to determine whether rats are suppressing these two highly invasive species.

Aerial baiting for rodent eradication programmes

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Aerial spread of cereal baits containing brodifacoum is the primary technique employed for rodent eradication programmes on islands. More recently, with the approval of a Code of Practice, this technique has been expanded to mainland sites surrounded by pest proof fences. Skywork Helicopters has put a considerable investment into the development and refinement of gear and equipment for aerial baiting. This is based on a system of continuous improvement and experience working on mainland sites such as Tawharanui Regional Park (Northland), Rotokare Scenic Reserve (Taranaki) and offshore islands including Little Barrier, Macauley Island, Rangitoto/Motutapu, Great Barrier and the Kaikoura Island chain. Aerial baiting operations for eradication programmes require exacting standards and the use of experienced pilots and ground crew. These operations are often conducted in remote environments and require effective logistical support and good problem solving skills. Planning and operational management of these operations requires good knowledge of the pest species present, the land area the operation is to be undertaken in, as well as factors that may influence a successful baiting operation, such as weather, steep cliffs, accuracy of helicopter buckets, and the use of DGPS navigational systems.

An attempt at a surveillance sensitivity comparison in Amami-ohshima Island, Japan

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Many endemic species in Japan, especially on small islands, are now threatened by invasive alien species. In 1979, the small Asian mongoose (*Herpestes javanicus*) was introduced to Amami-ohshima Island to control native poisonous habu snakes (*Protobothrops flavoviridis*). However, the mongoose has had a predatory impact on endemic animals. From 2005, the Ministry of the Environment began a 10 year project to eradicate the mongoose from the island. This has successfully decreased population density of the mongoose. Some scientists (e.g., John Parkes and Alan Saunders) gave advice about this project at the Symposium of Control Strategy of Invasive Alien Mammals 2008, held in Okinawa Japan. They advised that at the next stage, we should use the capture technique in the low density area, as well as a method to investigate the presence or absence of the mongoose. Responding to their advice, we plan to develop some methods to investigate the presence or absence of the mongoose. To do this, we need to know the relationship between known frequency and population density. At first, we will research to find a relationship between frequency, using a sensor camera and population density as it is thought that the photographed frequency is proportional to population density. We report on the design and the progress of our research.

Trap allocation strategy for the mongoose eradication project on Amami-Ohshima Island, Japan

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When the establishment of an invasive alien species has once been detected, we should take appropriate steps such as eradication, containment, or control. If eradication is not feasible, the goal of control is to maintain reduced population sizes or to prevent expansion of the distribution of the invasive species. There is a trade-off between high and low population density areas in population control. When the project manager allocates many traps in a center of distribution, the population may continue to expand from the margins. Eradication is only possible if spatial trap allocation is appropriate. In many cases, the project manager does not have sufficient information about the distribution of the target species. Therefore, trap allocation based on the capture results from the previous year is probably useful to control the target species. We examined effective trap allocation by using a lattice model in both cases whether eradication is possible or impossible. We suggest an effective trap allocation strategy using parameter values of small Indian mongoose (*Herpestes javanicus*) on Amami-Ohshima Island where a mongoose eradication project has been carried out by the Ministry of the Environment.

Canine detection of free-ranging brown treesnakes on Guam

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We investigated canine teams (dogs (*Canis familiaris*) and their handlers) on Guam as a potential tool for finding exotic brown treesnakes (*Boiga irregularis*) in the wild. Canine teams searched a defined 40m × 40m forested area with a snake that had consumed a dead mouse (*Mus musculus*) containing a radio-transmitter. To avoid tainting the target with human scent, no snake was handled prior to searches. Trials were conducted during the morning, when snakes were usually hidden in refugia. A tracker knew the snake's location, but dog handlers and data recorders did not. Of 85 trials conducted over 4 months, the two canine teams had an average success rate of 35% of correctly defining a 5m square area that contained the transmittered snake; the team with the most training had a success rate of 44% compared with 26% for the newer team. Eleven sheds from wild snakes were found and, although dogs alerted outside the location of transmittered snakes, only one wild, non-transmittered snake was found during the trials, possibly reflecting the difficulty humans have in locating snakes in refugia. We evaluated success at finding snakes as a function of canine team, time, canine success at the previous trial (we predicted that dogs that had been recently rewarded might be more successful), environmental conditions, cloud coverage, average humidity, average temperature, average wind speed, rain during trial, and rain in previous 6 hours), snake perch height, and snake characteristics (snout-vent length and sex). Success rate increased over the course of the trials, perhaps due to increased searching experience. Canine team success also increased with increasing average humidity and decreased with increasing average wind speed. Our results suggest that dogs could be useful at detecting snakes in refugia, but techniques are needed to help humans pinpoint a snake's location once a dog has alerted.

Restoration of globally important seabird islands in Fiji by the removal of rats

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Seabirds are becoming increasingly scarce among the more than 300 islands of the Fijian archipelago. Several reasons have been attributed to this. Key amongst these are the introduction of alien mammals to breeding islands, particularly rats (*Rattus* spp), feral cats (*Felis catus*), pigs (*Sus scrofa*) and dogs (*Canis familiaris*) and other anthropogenic influences such as fire and harvesting. In an effort to protect breeding seabird colonies in Fiji, BirdLife International Fiji Programme undertook an assessment of seabird islands identifying sites of national and global importance. Threat assessments confirmed the presence of at least one species of introduced mammalian predator on all islands. In 2006, following its identification as an Important Bird Area, Vatu-i-ra Island was subject to a Pacific rat (*Rattus exulans*) eradication operation, to remove the only invasive predator of seabirds from the island. This operation was a success and in 2008 was followed by rodent eradications from seven of the Ringgold Islands and Mabualau. Community consultation is a vital component to invasive species management in Fiji, as 75% of the land tenure is native owned. The development and implementation of these projects has been conducted using a participatory process where capacity development has been extended to landowning communities. Despite the achievements and local support for the restoration of seabird islands, the biggest challenge remains with the long term management and maintenance of pest free islands. The current approach to this is presented.

Management of the red crab (*Gecarcoidea natalis*) on Christmas Island, Indian Ocean: the efficacy of a yellow crazy ant (*Anoplolepis gracilipes*) baiting programme

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Christmas Island is located approximately 360km south of the western head of Java, Indonesia. One major biological feature of the island is the unusually high density of red crabs (*Gecarcoidea natalis*), which are considered a 'keystone species'. *Gecarcoidea natalis* can determine vegetation communities through their herbivory and limit the potential for colonisation by some introduced species. In the late 1990s, *G. natalis* was extirpated from large areas of Christmas Island after the formation of supercolonies by the introduced yellow crazy ant (*Anoplolepis gracilipes*). In response, Christmas Island National Parks embarked on a YCA supercolony baiting programme that has been running continually since 2001. Here we report on the outcomes of a biannual island-wide survey that has now been conducted five times to monitor changes in crab burrow densities relative to ant baiting. On each survey, occupied *G. natalis* burrows are counted along a 50 metre transect at 877 survey points across the island. We used a Bayesian hierarchical spatial model to show that despite the death of up to 33% of *G. natalis* in the early phase of ant supercolony formation, densities of crab burrows have remained stable since 2001. However, significant, but more localised changes in burrow densities occur on a regular basis, suggesting a dynamic system.

Improving "internal" biosecurity in the Falkland Islands: a pragmatic approach

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The Falkland Islands are an archipelago of more than 700 islands, with a wide range of sizes, topography, and ownership arrangements. Many islands are privately owned: some of these are farmed, and some have residences that are occupied for all or part of the year; other islands are uninhabited and treated as reserves or used for grazing livestock. The main transport methods between islands are private boats, a ferry, the Falkland Islands Government Air Service (light aircraft) and helicopters. There are three species of rodents present on the Falkland Islands: ship rats (*Rattus rattus*), Norwegian rats (*R. norvegicus*) and house mice (*Mus musculus*). Some islands have remained rodent-free, but many have one or two of these species present. Since 2001, a successful programme of rodent eradications has been undertaken on the Islands, with more than 20 islands cleared. With increasing numbers of rodent-free islands, reducing the risk of reinvasion (or new invasion) has become a growing priority. The recent emergence of new pest species has also raised the profile of biosecurity issues amongst landowners, the general public and the Falkland Islands Government. A pragmatic, non-regulatory approach has been taken to improve "internal" or inter-island biosecurity on the Falkland Islands in the last three years. Current worldwide best practices were investigated and elements from different programmes were selected to create a system of island biosecurity that would be manageable, cost-effective, and achievable for different landowners and users. This approach has involved improving public awareness and education rather than introducing legal regulations. This approach could be applied to other island groups where reducing the risk of pest invasion is important but legal regulations are lacking. This work was funded by the European Union's EDF-9 fund and the Falkland Islands Government, with support from island owners and Falklands Conservation.

When failure is not an option: applying new tools to rodent eradication planning

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Rodent eradication is often successfully used to protect native island biota from the negative impact of introduced rodents. However, as this tool is increasingly applied worldwide, standard eradication methodologies are being challenged by increasingly complex systems, e.g., commensal rodents, multi-island atolls and tropical ecosystems. To address these issues, Island Conservation applied three new tools to refine rodent eradication planning: a biomarker bait; hand-broadcast, using GIS; and genetic sampling protocols. On Palmyra Atoll and Wake Island (tropical Pacific) and Desecheo Island (Caribbean), a placebo bait, using the biomarker pyranine (a fluorescent dye), was used to determine bait application rates for high density *Rattus* sp. and commensal rodent populations, and to track bait consumption by land crabs and other invertebrate consumers, which are potential secondary sources of rodenticide for non-target predators. On Wake Island, placebo bait was hand-broadcast across 10 ha study plots using hand-held GPS units uploaded with a GIS layer of predefined points at which bait was broadcast. In the event of a rodent eradication failure, Island Conservation has also developed protocols for genetic sampling of rodent populations to determine if failure was due to re-emergence of a residual population or re-invasion from an outside source. Together, these tools have improved our efficiency of ground-based bait application, enabled a better understanding of non-target bait consumption, and overall have improved our rodent eradication planning, including learning from potential failures.

Community-based nutria control by traditional irrigation systems

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Nutria (*Myocastor coypus*) was originally farmed for its fur, but, since being abandoned, has naturalised in Honshu island, Japan. Especially in and around the agricultural regions of Hyogo Prefecture, this semi-aquatic mammal has rapidly expanded its distribution range in the last decade. From observations in Kasai City it was discovered that the nutria exhausted some aquatic plants and were threatening some invertebrate species, including an endangered Japanese dragonfly, *Libellula angelina*. Although nutria has been recognised as a serious invasive species in wetland ecosystems, it is difficult to eliminate them by hunting or trapping because their home ranges are within villages. To develop an ecological method to control the nutria population, we investigated their dispersal pattern and attempted to exclude them from some drainage systems using an irrigation technique in Kasai City. At first, from the analysis of records, we clarified that the nutria dispersed through non-manipulated irrigation canal systems and bred in the banks of ponds. We then contrasted their utilisation of canals and banks between manipulated and non-manipulated systems, and it was confirmed that nutria avoided fast currents as well as large fluctuations in water levels, probably because of their difficulties in moving and nesting. We tried to alter the water level and volumes of un-manipulated irrigation systems, mainly in winter season, and observed the movements of nutria. As a result they rarely moved from the lower to upper reaches. Nesting female groups abandoned their upriver nests and vegetation started to recover in the following year. In conclusion, reactivation of this old-style indigenous irrigation system is an effective and receptive (a community-based) method to control nutria and to restore the specific wetland ecosystem.

Accomplishments and impact of the NGO, Island Conservation, over 15 years (1994 – 2009)

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Since its inception in 1994, the NGO, Island Conservation, has removed 54 populations of 10 invasive vertebrates from 35 islands totalling >52,000ha. These actions have helped protect 233 populations of 181 insular endemic species and subspecies of plants and vertebrates and 288 populations of 54 species and subspecies of seabirds from the threat of local and global extinction. There were no reinvasions. One eradication attempt failed. These conservation actions and their apparent biodiversity impact demonstrate the potential of private organisations to protect biodiversity by eradicating invasive species from islands.

Snap-trapping, a viable alternative to ground-based poison operations for eradication and/or control of rats in island and mainland situations

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During development of the novel Ka Mate reverse-bait snap-trap, in 2009 450 of the traps were deployed over 75 ha of mature broadleaf/podocarp/kauri forest in Waiaro Sanctuary (Coromandel, New Zealand). The trials were designed to replicate with traps ground-based poison campaigns (e.g., the landmark 1988 eradication of rats from Breaksea Island), and test whether it was possible to achieve similar outcomes without the use of toxins. In Waiaro, rat-catch reduced significantly from 117 *Rattus rattus* killed on night one to less than fifty per check a week later. At six months, catches of 2-10 rats per check were only on the peripheral trap-lines, with no rat incursion or rat sign found within the core of the trapped area for more than three months. More than 800 rats were removed from the Sanctuary, all of which were clean-kill head-strikes. Despite the traps being set in open situations without protective stations, a few mice were the only non-target by-catch. The deployment, effectiveness and problems encountered with various trapping regimes, using a mix of trap types in programmes from wide-ranging localities and habitats worldwide (Seychelles Islands, New Caledonia, Wake Atoll, Hawaii, and several New Zealand sites) are also discussed.

The infection risk and pathogenicity of chytrid fungus *Batrachochytrium dendrobatidis* carried by the Japanese sword tailed newt

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Amphibian chytridiomycosis, caused by the chytrid fungus *Batrachochytrium dendrobatidis*, is a highly virulent disease of amphibians and is known to be a major driver of amphibian declines observed all over the world. In Japan, this fungus was first found in December 2006 from imported pet frogs. The nationwide investigation to assess the risk of pandemic chytridiomycosis to Japanese frogs elucidated that this fungus is distributed all over the Japanese main islands and that the genetic diversity of Japanese chytrid fungus, including more than 30 haplotypes, is much higher than those of fungus in other countries. Thus, several researchers currently consider that Japanese islands are one of the native localities of this fungus and that amphibian chytridiomycosis observed elsewhere in the world might be caused by the fungus derived from Japan. To verify this "Chytridiomycosis out of Asia hypothesis", we surveyed the infection risk and pathogenicity of the chytrid fungus carried by Japanese amphibians. In experimental infection, the chytrid fungus carried by Japanese sword tailed newt (*Cynops ensicauda*) infected South American horned frog (*Ceratophrys ornata*). All frogs infected by Japanese chytrid fungus showed an onset of amphibian chytridiomycosis. Given that Japanese amphibians, including sword tailed newt, frequently have been exported to foreign countries as pets, we must consider that the chytrid fungus carried by Japanese amphibians would also be introduced to foreign countries leading to amphibian chytridiomycosis of native species in host areas.

Coordination mechanisms for invasive species action in the Pacific

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Islands are exceptionally vulnerable to invasive species impacts, but small island nations often do not have the human or financial resources to tackle these threats adequately by themselves, especially projects with heavy one-off costs such as eradications. Pacific nations and territories have a long history of cooperation to enable them to overcome such limitations. Mechanisms and tools have been established to promote collaboration and effective action against invasives in the Pacific, which can serve as models for elsewhere, particularly other oceanic regions. The Pacific Invasives Partnership promotes coordinated prioritisation and assistance from regional and international agencies to countries and territories of the region. Its members include regional intergovernmental agencies, NGOs and other organisations working on invasives issues in more than one Pacific country or territory. The partnership is supported by two regional initiatives: the Pacific Invasives Learning Network, which is a professional aid network for invasive species workers in Pacific countries and territories to facilitate collaboration and exchange of information and skills; and the Pacific Invasives Initiative, which provides assistance with project development, training and links to expertise. These programmes help build local capacity in different ways. A guiding strategy, the Guidelines for Invasive Species Management in the Pacific forms a framework for action by all of them, in which eradication is emphasised as the preferred management objective for established invasives when feasible. The overall goal of these regional initiatives is to assist Pacific island countries and territories in planning and achieving more effective invasive species management.

Dogs working for conservation

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Dogs (*Canis familiaris*) have assisted with mammal eradications in New Zealand for the last 30 years. Since 2002, the Department of Conservation has run a dedicated predator detection dog programme providing dog and handler training and certification, systems development and improvement, a breeding programme and operational support. The dogs are trained to detect the presence of mammalian predators and browsers, including rodents, mustelids, cats (*Felis catus)* and rabbits (*Oryctolagus cuniculus)* for the purposes of audit, incursion contingency response, surveillance, biosecurity quarantine and optimising trap placement. Dogs have proved to be an extremely effective tool for confirming presence when predator numbers are low and other predator detection methods (tracking tunnels, traps, gnaw sticks) are less efficient. Once detected by dogs, the predators are killed using pesticides, traps, or shooting. Since the programme started, these dogs have been involved in many successful pest eradication programmes on islands. The NZ dog programme has also provided international advice, training, and dogs (practical support) for eradication programmes e.g., Macquarie Island, Australia (rabbits) and Amami Island, Japan (mongoose, *Herpestes javanicus*). This paper presents the dog programme and illustrates case studies where use of the dog programme has assisted eradications, including: Raoul Island (cats), Campbell Island (cats and Norway rats, *Rattus norvegicus*), Secretary Island (stoats, *Mustela erminea*), Te Kakahu/ Chalky Island (stoats), Tuhua/Mayor Island (cats), and many contingencies including Motuihe Island where the rodent dog detected the rat within 48 hours of tracks being discovered on tracking cards.

Risk analysis of potential freshwater nuisance fish and other species associated with increased U.S. military presence in Guam and circum-Pacific islands

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The islands of Micronesia have low taxonomic richness of strictly freshwater aquatic species, yet endemism on single islands or island groups is often high. In contrast, non-native aquatic organisms have become increasingly common. Although published reports differ in total numbers, approximately 70-90 species of fish have been introduced into fresh (and some brackish) waters of the western Pacific and Hawaiian islands. In addition to fish, non-indigenous freshwater molluscs and crustaceans have also been introduced. Sources of introductions vary from some that were intentional (e.g., for aquaculture, ornamental trade, mosquito control), to those of accidental or unknown pathways. The ecological and economic effects of these introductions are poorly understood and generally have not been quantified. The U.S. Department of Defense (DoD) projects manifold military operations in the western Pacific, centred in Guam and the Commonwealth of Northern Mariana Islands. Increased traffic of cargo and personnel associated with the expansion of military operations poses elevated risk of the transport of invasive species throughout the region. Consequently, freshwater systems of Micronesian islands and their vertebrate and invertebrate faunas are in need of greater study to determine the extent of threats to the native biota. This project provides a freshwater component to a multi-agency and multi-disciplinary endeavour to evaluate control and management protocols for existing and potential invasive species, as part of a collaborative process to prepare a region-wide environmental impact assessment. The first steps in developing an effective biosecurity programme are to conduct risk analyses of pathways of introductions, to identify and characterise those species having the highest potential of becoming invasive, and to document impacts to native communities. Major goals of the DoD biosecurity plan are to prevent new introductions and reduce the risk of spread of potentially invasive marine, terrestrial, and freshwater species. The risk analysis process will require the identification of endpoints, hazards, and the likelihood and consequences of different risks.

Plant responses following eradication of goats and rats from Raoul Island, Kermadecs

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Goats (*Capra hircus*) were eradicated from Raoul Island in 1986. Some changes apparent in the vegetation as a consequence were: thickening of the pohutukawa canopy; reduction in the dominance of the invasive aroid lily (*Alocasia brisbanensis*) in the forest understorey; increase in the abundance of a) *Hebe breviracemosa* (from one plant to several discrete natural populations); and b) *Pseudopanax kermadecensis*. Rats (*Rattus norvegicus* and *R. exulans*) were eradicated in 2002, leaving no introduced mammals to affect vegetation. Some plant responses observed following rat eradications are: 100-fold increase in germination of nikau (*Rhopalostylis baueriana*) seeds; *Homalanthus polyandrus* seedlings visible widely on the island; and many orange seedlings (*Citrus sinensis*). Most species that did not fruit in the presence of rats are now fruiting e.g., *Hibiscus tiliaceus*, *Catharanthus roseus*, *Bryophyllum pinnatum* and seedlings of those species are establishing. Consequences of the removal of all mammalian browsing pressure are two-fold. Potentially, vegetation succession can return to natural trajectories. The goals for management of some exotic plant species may need to be revised: ideally, *Catharanthus roseus* and *Bryophyllum pinnatum* should be eradicated.

Management of invasive vertebrate species in the United States

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Many invasive vertebrates have become established in the United States and its territories, including at least 20 mammalian, 97 avian, and 53 reptilian/amphibian species. Species from "100 of the World's Worst Invasive Alien Species" are included in each taxonomic group: domestic cat (*Felis catus*), small Indian mongoose (*Herpestes javanicus*), red fox (*Vulpes vulpes*), goat (*Capra hircus*), pig (*Sus scrofa*), rabbit (*Oryctolagus cuniculus*), rat (*Rattus* spp.), house mouse (*Mus musculus*), grey squirrel (*Sciurus carolinensis*), nutria (*Myocastor coypus*), starling (*Sturnus vulgaris*), Indian common myna (*Acridotheres tristis*), red-vented bulbul (*Pycnonotus cafer*), brown tree snake (*Boiga irregularis*), and red-eared slider (*Trachemys scripta*). I briefly review some of these species and the types of damage they cause. I then review the basic types of methods used for control or eradication of each taxonomic group, including physical, chemical, biological and cultural methods. I discuss some of the challenges in managing these species, including issues with the use of toxicants, land access, public attitudes and monitoring difficulties. Finally, I list some ongoing research and future research needs, including fertility control, improved detection methods, improved attractants, improved barriers, improved capture methods and risk assessment methods.

Damage to plants and seabirds by ship rats *Rattus rattus* on the Ogasawara (Bonin) Islands before eradication

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Damage by ship rats (*Rattus rattus*) to plants and seabirds on the Ogasawara Islands, southern Japan disappeared after eradication campaigns conducted using diphacinone rodenticides. Ship rats damage the twigs of endemic trees, *Ochrosia nakaiana* and *Hibiscus glaber*, and feed on the fruits of *Pandanus boninensis* on Nishijima, a 49 ha uninhabited island. Analyses of the rats' age compositions and food habits suggested that they ate soft tissues of twigs due to the shortage of food in winter. Age compositions of ship rats also showed that the season for plant damage corresponded with that of low breeding activities of the rats and scarcity of preferred foods (January – March). *Pandanus* fruits were found to be gnawed all year round, however, such damage stopped after an eradication campaign in March 2007. In April 2008, we found only 82 *Pandanus* fruits remained undamaged on the island. Ship rats also consumed Bulwer's petrels (*Bulweria bulwerii*) on Higashijima, a 28 ha uninhabited island. The meat and feathers of the seabirds were found in 16 stomachs (36%) of 44 rats caught in traps in June 2008. The average body mass of bird-eating rats was significantly larger than that of non-bird-eaters at the 5% significance level. Bird-eating rats ranged from 167 to 253 g body mass, and they were larger than the Bulwer's petrels (78 – 130 g in general).

Surveillance of mongoose and Amami rabbit by auto cameras during mongoose control programmes on Amami-Ohshima Island, Japan

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An invasive small Indian mongoose (*Herpestes javanicus*) (Family Herpestidae, Order Carnivore, Mammalia) in Amami-Ohshima and Okinawa Islands, and in Kagoshima City in Kyusyu was recognised in 2009 as one of the most damaging invasive mammals in Japan. During 2000-2004 and 2005-2014, some control and eradication programmes against the mongoose were implemented by the Japanese government as a model for conservation of biodiversity in subtropical islands. We used 20-40 sets of auto sensor cameras to monitor mongoose and its impacts on native species, especially on Amami rabbit (*Pentalagus furnessi*), which is an endangered species and one of the flagship species on Amami-Ohshima Island,. Mongooses were recorded in early stage of the operations at rabbit nesting areas. After mongoose control, records of mongoose ceased whereas those for rabbits became more frequent. Even at sites with high mongoose and low rabbit numbers, mongoose records ceased after control and rabbit numbers recovered. These results indicate the vulnerability of the Amami rabbit to mongoose invasion.

Lessons learned from gaining political and community support of Hawai`i's first predator-proof fence at Ka`ena Point Natural Area Reserve

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The coastal strand ecosystem of the Ka`ena Point Natural Area Reserve on the island of Oahu, Hawai`i hosts one of the largest seabird colonies in the main Hawaiian Islands, and contains up to 11 species of endangered plants. It is also one of the most culturally significant sites in Hawai`i where souls are said to leap into the afterlife. Due to the negative impacts of invasive mammals on native species, construction of a predator-proof fence was planned for late 2009 and the five invasive mammal species present will subsequently be removed. Prior to construction, two and a half years of extensive public outreach was completed. These efforts reached over 1800 individuals directly, in addition to the thousands that were reached via 11 printed news stories (both local and national), and airing of seven unique television pieces. As a result of these efforts, what was considered a controversial project has achieved broad public support and resulted in the formation of a community and school group dedicated to helping protect the area. During outreach efforts, extensive ecological monitoring was conducted on both native and non-native species to document the effects of predator removal and to determine how best to eradicate the predators present, with the public occasionally participating in this monitoring. The exclusion and removal of these predatory animals is anticipated to result in an increase in the existing population of nesting seabirds, encourage new seabird species to nest at Ka`ena Point, and enhance regeneration and recruitment of native plants and invertebrates. Perhaps just as significant, this project has increased the public awareness of restoration techniques and will provide the people of Hawai`i with a rare opportunity to visit a restored ecosystem.