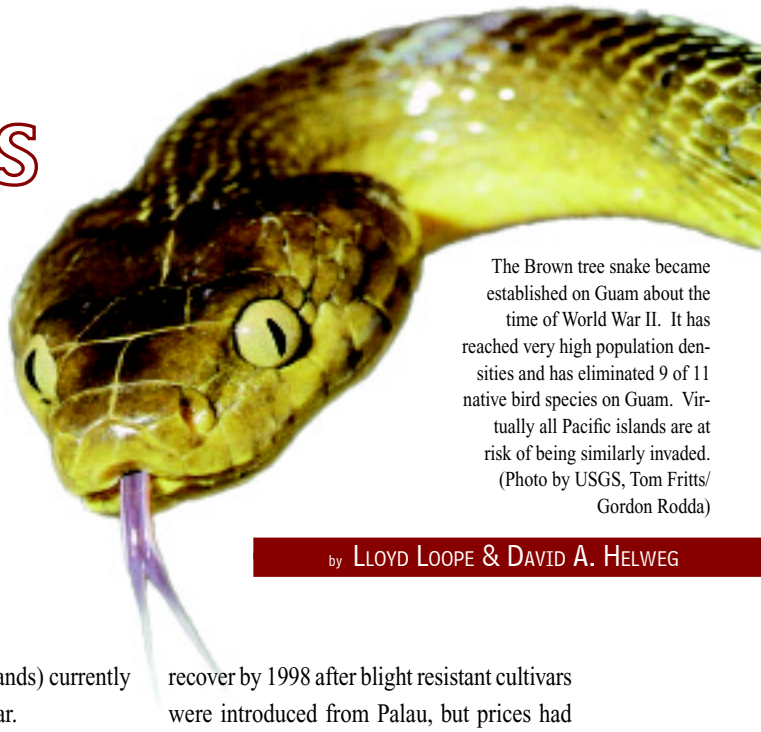
# Invasive species prevention for oceanic islands



The Brown tree snake became established on Guam about the time of World War II. It has reached very high population densities and has eliminated 9 of 11 native bird species on Guam. Virtually all Pacific islands are at risk of being similarly invaded. (Photo by USGS, Tom Fritts/ Gordon Rodda)

by Lloyd Loope & David A. Helweg

## Background

Humans have been moving species of animals and plants beyond their native ranges, both deliberately and inadvertently, and many of these species have become established and spread. The phenomenon is increasing to the point that biological invasions have become a widespread and significant component of global change (Vitousek et al. 1997), and the term "invasive species" is currently widely applied to the non-native species that cause damage. It has long been known that invasive species establish more easily on oceanic islands and that island animals, plants, and human well-being are highly vulnerable to effects of invasions.

Some of the more dramatic recent examples of effects of invasive species on islands include the following:

• The invasive neotropical tree *Miconia calvescens* has demonstrated in French Polynesia that it is capable of establishing in the shaded understory of moist forest of Pacific islands, rapidly gaining complete canopy dominance, and drastically impoverishing biodiversity (Meyer 1996). *M. calvescens* was introduced to Tahiti in 1937; by the 1990s, displacement by this aggressive invader alone had reduced 40-50 endemic plant species to the verge of extinction (Meyer and Florence 1996). Spread to other islands in French Polynesia (tiny seeds hitchhike on dirty construction equipment, for example) is rampant in spite of precautions to date. *M. calvescens* was brought to the Hawaiian Islands by the early 1960s and is now the most problematic invasive plant species in the high islands of that archipelago with annual containment costs (on four islands) currently in excess of $2 million per year.

• Brown tree snake (*Boiga irregularis*) was once just another ordinary snake native to the Solomon Islands, Papua New Guinea, and northern Australia. It became established on Guam about the time of World War II and has since attained population densities of 4,000-12,000 per km$^2$ (10,000-30,000 per mi$^2$), feeding on birds, rats, shrews, and lizards. Nine of the 11 native bird species on Guam in 1945 have been eliminated by the snake (Savidge 1987). Guam is a hub of transportation, thus the high densities of snakes and their nocturnal habits make the probability of stowaways in air and ship cargo very high. Spread to some islands of the Northern Marianas has already occurred. Virtually all Pacific islands are at risk of being invaded. Measures are in place, funded by several U.S. agencies, to reduce snake populations at ports and conduct surveillance of cargo leaving Guam for Hawaii, but cooperation by the shipping companies is voluntary, not mandatory. Nevertheless, whereas seven brown tree snakes had been detected during 1981-94 in Hawaii, in association with flights from Guam, none have been detected in Hawaii since 1994.

• Traditionally, the most important food plant in Samoa was taro (*Colocasia esculenta*, Araceae), and in the early 1990s taro was the main agricultural export of those islands. An epidemic of taro leaf blight struck Samoa in 1993-94. All Samoan taro cultivars were susceptible to the fungus (*Phytophthora colocasiae*), and production in both (Western) Samoa and American Samoa was quickly reduced to near zero. Production started to recover by 1998 after blight resistant cultivars were introduced from Palau, but prices had more than quadrupled (Anonymous 2000).

• Australian researchers (O'Dowd et al. 2003) recently described what they referred to as "invasional meltdown" on Christmas Island in the Indian ocean south of Java, involving the invasive ant *Anoplolepis gracilipes* and two non-native scale insects. The researchers had been since the late-1980s studying the island ecosystem, especially notable because of the important role of red land crabs. Their

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research had shown that the native crabs have a controlling effect on the forest structure; the understory was largely eliminated by feeding of the omnivorous crabs during cycles when they were abundant. Beginning in the mid-1990s, supercolonies of the ant began to build up and spread, eventually eliminating the crabs locally over about 20% of the island. The cause of the dramatic local ant population buildup was exploitation by the ants of the honeydew food source produced by the scale insects in the forest canopy, in well-known, though usually less dramatic, ant-insect mutualism. The ant populations killed all crabs within the most vigorous ant supercolonies. Meanwhile, the forest canopy is dying because of sooty molds encompassing almost the entire leaf area of the forest canopy (O'Dowd et al. 2003), promoted by honeydew produced by the scale insects. Similar invasive ant-scale insect mutualisms have caused severe decline of *Pisonia* forest on Rose Atoll (Samoa) and Palmyra Atoll (Line Islands) and probably elsewhere. Of significant concern is the opportunistic nature of ant-insect mutualism leading to forest death, potential for which increases with the spread of invasive ants and scale insects.

• Few endemic Pacific land snail species can now be regarded as secure, largely as a result of predation by the prolific and voracious snail *Euglandina rosea*, first introduced by the Hawaii Department of Agriculture in 1958 as an agent to control, unsuccessfully, the giant African snail (*Achatina fulica*), which reached Hawaii in 1936 as an ill-advised and worthless food source (Cowie 2000). Tragedy for native Pacific biodiversity unfolded as both the African snail and its purported biocontrol agent were spread purposely by humans to most island groups. Extinction in remote island forests is always difficult to document but one of the best cause-and-effect cases ever reported was that of researchers on Moorea (French Polynesia), where endemic land snail (14 species of *Partula*) populations had been studied for genetic and evolutionary insights since the 1920s. *Achatina* was introduced to Moorea by 1970, followed by *Euglandina* in 1977. Researchers documented the spread of *Euglandina* and decline of the endemics; by 1987, no *Partula* were found (Johnson et al. 1984; Murray et al. 1988). Sadly, similar scenarios played out without documentation across the Pacific. Though *Euglandina* has not yet reached all islands, only concerted efforts at prevention will stop the continued spread. A recent note by Meyer (2003) confirms that endemic snails still thrive on an island (Ua Huka) in the Marquesas (French Polynesia) where *Euglandina* is absent.

• The Red Imported Fire Ant (RIFA; *Solenopsis invicta),* native to South America and dispersed primarily through human commerce, has invaded over 120 million hectares in the southern United States since the 1930s in spite of a federal quarantine by the U.S. Depatment of Agriculture (USDA). It is a serious threat to public health and safety, industry, biodiversity, water quality, economy, and quality-of-life. Its aggressive nature and powerful sting have caused the deaths of at least 83 people, injury to tens of thousands of people annually, and injury and death of wildlife, livestock, and pets (Vinson 1997). Its broad diet, which includes plants and animals, has caused substantial agricultural damage and declines in biodiversity. RIFA reached California in 1998 and Queensland, Australia, in 2001. It is still sparse in California, but is very likely to spread widely in the state to locations including four major international airports and the largest shipping port on the west coast (Long Beach). This situation poses an immense threat to Hawaii and other Pacific islands. Australia is still very much involved in an eradication effort for RIFA, but the threat from Australia cannot be discounted. Within the past 20 years, RIFA has invaded numerous Caribbean islands from Florida – all the way to Trinidad (Davis *et al.* 2001) – and is capable of doing the same in the Pacific unless concerted action is taken. Based on a preliminary risk assessment for Hawaii, RIFA could occupy most habitats except rainforest, from sea level to above 3000 m elevation. Wherever RIFA reaches Pacific islands, it is likely to be extremely damaging to biodiversity, economy, and culture. Impacts to human quality-of-life can be expected to be most serious in island societies where living is close to the land. Biodiversity impacts will likely be most severe in archipelagoes where native fauna largely or entirely evolved in the absence of predatory ants and is consequently extremely vulnerable to aggressive ants (Gillespie and Reimer 1993).

Arriving containers at the Port of Auckland. New Zealand's Ministry of Agriculture and Forestry is at the forefront of exploring techniques for reducing the risk of pest introduction via burgeoning sea and air container traffic. (Photo by Philip Thomas, USGS.)


## Islands have special need for invasive species prevention

Given the severe consequences of invasions for islands, one might assume that citizens of the world would exercise special care for oceanic islands through adopting stringent measures for preventing new invasions – but largely that has not been the case. The

On the island of Maui, Hawaii, over US$1,000,000 is currently being spent annually to contain the aggressive invader *Miconia calvescens* to protect native biodiversity and watersheds. (Photo from www.hear.org)

concept of quarantine originated in 14th century Venice for protection of human populations from ships harboring bubonic plague. Sustained border-protection quarantine was first adopted by many governments near the end of the 19th or early 20th century to prevent spread of agricultural pests, one of the more dramatic of which was the infection of vineyards in Europe in the 1860s with the North American plant louse *Phylloxera*. There has been an evolution over the ensuing century toward common standards among countries for border protection quarantine. This has led to the currently definitive Treaty for Sanitary and Phytosanitary Measures within the framework of the World Trade Organization (WTO 1998). The treaty is managed by the U.N. Food and Agricultural Organization which is also responsible for implementing the closely related International Plant Protection Convention (FAO 2001).

A major challenge, especially for islands concerned about protecting their biodiversity, is the largely agricultural focus of the border-protection quarantine system worldwide, a system built by and for agricultural interests. This means that to be effective, biodiversity interests have to work with agricultural interests, and must be prepared to work towards development of mutual confidence and capacity. But, as suggested below, New Zealand (Aotearoa) is demonstrating that a hybrid system (for protection of both agriculture and biodiversity) can work well – given political will, public support, flexible government, and ability to cooperate across sectors. New Zealand's seemingly workable model may provide an inspiration for other islands of the world.

## How are some island groups coping with the challenge of invasive species prevention?

### Hawaiian Islands

The Hawaiian Islands comprise a world-renowned microcosm of biological evolution in a diverse, isolated island system, with roughly 10,000 species of animals and plants endemic to the archipelago (Miller and Eldredge 1996). One might expect Hawaii, as part of the USA, to possess a first-rate system of border protection, but this is not the case, in spite of its dramatic vulnerability to invasions. One entomologist (McGregor 1973) calculated 30 years ago that, given the fact that Hawaii had roughly the same number of established non-native insect and mite species as the continental United States, the rate per unit area of introduction to Hawaii was 500 times that of the rest of the United States.

Invasive species prevention in Hawaii is very complicated because Hawaii is a state of the United States. A main quarantine concern for the United States involves protecting mainstream agriculture in California and other states from fruit flies (Diptera: Tephritidae) and other pests which reached Hawaii long ago. When Hawaii was still a U.S. territory in 1912, the U.S. instituted a major quarantine to prevent fruit flies from reaching the U.S. mainland. This program persists today. Federal inspectors at Hawaii's airports screen baggage and hand carried items for passengers bound for the U.S. mainland. In contrast, the quarantine for protection of Hawaii from pests from the U.S. mainland is funded and implemented not by the federal government but by the state government, which has limited jurisdiction. A further problem is that federal inspection of international arrivals focuses on essentially the same target pests of concern at all U.S. ports for protection of mainstream agriculture, and the state has no authority to inspect international arrivals. Moreover, coordination between federal and state efforts for dealing with specific shipments is complex and ineffective. The highest current priorities of the State of Hawaii's border protection include: Rabies, Brown Tree Snake, Red Imported Fire Ant, and the mosquito-borne West Nile Virus. Federal programs provide major assistance for protection from Brown Tree Snake but not for the others.

Invasions continue unabated and pose overwhelmingly the greatest current threat to Hawaii's endemic biodiversity, while also jeopardizing the state's economy, agriculture, health, and quality-of-life. Hawaii's needs for prevention and management of invasive species are substantial, and it is clear that those needs are not nearly being met (OTA 1993).

*Miconia calvescens*, an invasive tree from the neotropics, has demonstrated clearly in Tahiti its ability to displace Pacific island forests and obliterate native biodiversity in moist environments. The understory of miconia-invaded forest is devoid of vegetation. (Photo by Jean-Yves Meyer, Delegation de la Recherche, Polynesie Francaise.)

There has been much interest for more than a decade in Hawaii in improving efforts for prevention of invasions (e.g., NRDC/TNCH1992; Holt 1996), but to date little or no improvement is apparent, a situation that clouds the future of biodiversity in the Hawaiian Islands (Loope 1998; Loope et al. 2001). The reasons for slow progress of the federal-state political system towards improvement of Hawaii's border protection are complex, but involve inadequate (though growing) state and federal public and political understanding and the lack of broad pressure for change in the face of the many competing problems of modern society. No single agency can be blamed for the current lethargy. Unless this situation is turned around soon, Hawaii's biodiversity will become irreparably marginalized.

## New Zealand (Aotearoa)

In contrast to slow progress in Hawaii, New Zealand provides a striking contrast and an inspiring model of what is possible. New Zealand's problems with biological invasions fully rival those of Hawaii, but the country currently exhibits remarkable determination to reverse trends of ecological degradation through restoration (e.g., Veitch and Clout 2002) and to effectively prevent continuing invasions with a strong border protection quarantine system. New Zealand is a highly entrepreneurial country, and it shares most of the problems of modern society found in Hawaii, but its citizens understand the economic and ecological consequences of invasive pests. Border protection quarantine and surveillance have good legislative and financial support only because the public in New Zealand is very supportive.

Key aspects of New Zealand's border protection quarantine program are as follows:

- The Biosecurity Act of 1993 is New Zealand's major piece of legislation relating to measures for keeping new invasive pests out of the country to prevent economic, social, and environmental damage. It provides a range of functions, powers, and options for the management of harmful organisms. Although a number of governmental departments are involved in biosecurity, primary responsibility for implementation falls to a single department, the Ministry of Agriculture and Forestry (MAF). MAF's Quarantine Service (MQS) is the agency responsible for implementing the country's border protection quarantine.
- Import Health Standards (IHS) are the mechanism for defining conditions which must be met for importing risk goods to New Zealand. IHSs are based on risk analyses, consistent with standards set by the World Trade Organization and other treaties governing international trade.
- MQS uses rational rules, excellent explanatory material, and meaningful penalties. Upon entering the country, travelers are asked to complete a form declaring any prohibited items before passing through a checkpoint where X-ray machines and dogs are utilized to detect prohibited items. In June 2001, the Government introduced a system of instant NZ$200 fines for travelers to New Zealand who make erroneous biosecurity declarations; 2.5 fines per 1,000 travelers were assessed during the first year. The fines have resulted in efficient word-of-mouth spread of New Zealand's regulations. Inspection of passengers and baggage is fast and efficient. The system of screening passengers and their baggage at the airport is believed to be about 95% effective, evaluated by challenging the detection system with clandestine known items.
- All incoming international mail is inspected for prohibited items using X-ray machines and/or dogs. MAF estimates that only 1% of prohibited material gets through. Whereas relatively passive beagles are used when dealing directly with the traveling public, so-called active dogs are used for mail and cargo to sniff out illegal items.
- Air and sea cargo inspection is less thorough than that for arriving international passengers and mail, but the most crucial pathways such as used cars from Asia are thoroughly inspected, and other pathways are sampled to determine and discourage risk. Continual re-evaluation is an important component of the entire system; a review of the pest risk from sea containers has recently been completed (MAF 2003), and new Import Health Standards for Sea Containers issued.
- MAF has a branch targeted at detecting and responding to "post-border incursions" of unwanted pests before they are able to achieve firm establishment in New Zealand. The most dramatic such recent response involved the Red Imported Fire Ant. A mature (later estimated at 9 months to 2 years old) mounded nest of this notorious pest ant was detected and reported by a grounds maintenance worker at Auckland International Airport in March 2001. The nest was promptly treated with insecticide. The discovery triggered two years of intensive searching around the incursion site as well as a national awareness program, a national invasive ant surveillance program, and funding for an invasive pest ant risk assessment (A. Pascoe 2003 and pers. comm.).

Managing the biosecurity risks in the air and sea container pathways poses substantial challenges for New Zealand's quarantine system. The recently completed "Sea Container Review"

*Eleutherodactylus coqui,* an invasive frog from Puerto Rico, has reached all four main Hawaiian islands, probably via nursery stock, and poses a huge threat to biodiversity and quality-of-life of Hawaii and other Pacific Islands. (Photo by Allen Allison, B.P. Bishop Museum, Honolulu)

Red Imported Fire Ant (*Solenopsis invicta*) poses a huge threat to biodiversity, economies, and quality-of-life for all Pacific Islands. (Photo courtesy of Texas A&M University Fire Ant Project)

(MAF 2003) defined the problems clearly. For example, nearly half the sea containers contained wood packaging material, 60% of which was found to be unmentioned in the manifest (the required document in which the importer describes what is in the container) and 16% (mostly within the un-manifested category) of which required fumigation. The review recognized a remarkable opportunity for risk mitigation to overcome existing challenges through an electronic intelligence-based risk-assessment system (vs. the current, relatively unmanageable manual manifest system). Opportunity for requiring electronic manifests may be facilitated by the U.S. Department of Homeland Security's new "Container Security Initiative" or CSI (http://www.cbp.gov/xp/cgov/import/cargo_control/csi), which requires exporters to the U.S. to deliver electronic detailed and accurate manifest information 24 hours in advance of a shipment. (The CSI currently applies only to the world's 20 largest exporting ports but other ports are already being phased in.) New Zealand sees this as an opportunity to greatly improve the ability to assure cleanliness of sea containers, since all countries will have to provide such information to the U.S. anyway. Options may exist to require detailed and accurate manifest information for container contents, including information on the packing material; to deny loading to containers with inaccurate information; to impose penalties for mis-manifested cargo; and to place alerts on containers with high-risk goods and allow exporters the option of decontamination and certification overseas (MAF 2003).

The remarkable dedication of New Zealand's government and citizens to pursue a maximally effective strategy for prevention of new damaging invasions and rapid response to incipient invasions can be grasped by exploring their website (www.maf.govt.nz).

## Galapagos Archipelago

The Galapagos archipelago has much in common with Hawaii as a roughly comparable microcosm of evolution in isolation, and is similarly susceptible to biological invasions. Yet Galapagos has been fortunate in its relative lack of degradation: for example, whereas Hawaii has lost 75% of its original bird fauna, Galapagos has not yet lost a single bird species (Loope et al. 1988). Increased human movement to Galapagos in recent decades increased the risk of alien species introduction through various pathways such as cargo boats and airplanes. After much deliberation, to prevent further incursions, the Galapagos inspection and quarantine system was established in 2000, based on Ecuadorian legislation passed in 1998. The Charles Darwin Research Station assists the Ecuadorian Plant Quarantine Service in implementing this quarantine system. The quarantine's operation is funded from 5% of fee of US$100 entry fee, collected from every visitor to Galapagos National Park. The Galapagos quarantine is just getting started but has much promise for reducing future invasions to those islands.

## Pacific Island Countries and Territories

Pacific island countries and territories (PICT) comprise 25+ countries, most of which are served by two important regional international organizations, the Secretariat of the Pacific Community (or SPC, which addresses agricultural issues) and the South Pacific Regional Environment Programme (or SPREP, which addresses biodiversity issues). Biodiversity of PICT is particularly vulnerable to effects of invasive species (SPREP 2000). Ant invasions already plague many Pacific islands, but special concern has arisen recently, now that the highly invasive Red Imported Fire Ant (RIFA) occurs at or near the coast on both sides of the Pacific. What is the prognosis for a successful Pacific regional prevention program for RIFA?

The SPC-Plant Protection Service (PPS), based in Suva, Fiji, works in partnership with 22 PICT to maintain effective quarantine systems that limit incursions of new pests, diseases and weeds and to assist with regionally coordinated eradication/containment efforts when a pest incursion happens. Priorities for emphasis are determined by member countries, which meet periodically as the Pacific Plant Protection Organization (PPPO). The most concerted and successful effort of PPPO and SPC-PPS to date has involved a regional program to address the many species of invasive host-specific fruit flies (Diptera: Tephritidae) that damage crops and reduce the ability of the countries to export much of their agricultural produce, thus substantially

reducing potential for putting food on the table. (see www.spc.org/pps)

A major Pacific island conservation meeting in Rarotonga in July, 2002, sponsored by SPREP and others, recommended prevention of new terrestrial and marine species introductions through implementation of improved quarantine legislation and practices. SPREP's regional invasive species strategy already involves conducting training of countries' quarantine personnel to address issues relating to biodiversity needs; the first training session took place during the summer of 2003.

The decision of whether to address regionally the potential invasion of the Red Imported Fire Ant and other ants as high priority rests with the PICT and PPPO. If they should decide on its priority, there would be an unprecedented opportunity for agriculture and conservation interests to work together with international and bilateral aid entities at regional and country levels to build much needed quarantine capacity to give PICT the protection they desperately need to address invasions which jeopardize both agriculture and biodiversity.

## Conclusions

Invasive species pose the primary threat to biodiversity on most oceanic islands. New terrestrial and aquatic/marine invasive plant and animal species threaten to overwhelm Galapagos, Hawaii, New Zealand and all Pacific islands with ecological and economic damage and social costs. In spite of their vulnerabilities, oceanic islands have the opportunity to follow the lead of New Zealand in implementing much improved measures for prevention of new invasions. Key prerequisites for progress include obtaining broad public support and the cooperation of agriculture and biodiversity interests.

## References


ANONYMOUS. 2000. Taro leaf blight (leaflet). Pests and diseases of American Samoa, No. 3. American Samoa Community College, Agriculture, Human & Natural Resources, Cooperative Research & Extension.

CLARKE, B., J. MURRAY, and M.S. JOHNSON. 1984. The extinction of endemic species by a program of biological control. Pacific Science 38:97-104.

COWIE, R.H. 2000. Non-indigenous land and freshwater molluscs in the islands of the Pacific: conservation impacts and threats. Pages 143-166 in G. Sherley (ed.), Invasive species in the Pacific: A technical review and draft regional strategy. South Pacific Regional Environment Programme. Apia, Samoa.

DAVIS, L.R., R.K. VANDER MEER, and S.D. PORTER. 2001. Red imported fire ants expand their range across the West Indies. Florida Entomologist 84(4):735-736.

FAO (U.N Food and Agricultural Organization). 2001. International Plant Protection Convention – 2001 version. (www.ippc.int/IPP/En/default.htm, accessed October 2003).

GILLESPIE, R.G., and N. J. REIMER. 1993. The effect of alien predatory ants (Hymenoptera: Formicidae) on Hawaiian endemic spiders (Araneae: Tetragnathidae). Pacific Science 47:21-33.

HOLT, A. 1996 (1999). An alliance of biodiversity, health, agriculture, and business interests for improved alien species management in Hawaii. Pp. 155-160 *in* O.T. Sandlund, P.J. Schei, and A. Viken (editors). 1996. Proceedings of the Norway/UN Conference on Alien Species. Directorate for Nature Management and Norwegian Institute for Nature Research, Trondheim, Norway. (Springer-Verlag 1999) (http://www.hear.org/AlienSpeciesInHawaii/articles/norway.htm, accessed April 2003)

LOOPE, L.L. 1998. Hawaii and Pacific islands. Pages 747-774 *in* M.J. Mac, P.A.

OPLER, C.E. PUCKETT HAECKER, and P.D. DORAN (editors). Status and trends of the nation's biological resources, Volume 2. U.S. Department of the Interior, U.S. Geological Survey, Reston, VA. (http://www.hear.org/AlienSpeciesInHawaii/articles/hawaii_and_the_Pacific.pdf, accessed October 2003)

LOOPE, L.L., O.H. HAMANN, and C.P. STONE. 1988. Comparative conservation biology of oceanic archipelagoes: Hawaii and the Galapagos. BioScience 34(4): 272-282

LOOPE, L.L., F.G. HOWARTH, F. KRAUS, and T.K. PRATT. 2001. Newly emergent and future threats of alien species to Pacific landbirds and ecosystems. Studies in Avian Biology (Cooper Ornithological Society) 22:291-394.

MAF. 2003. Sea Container Review. MAF Discussion Paper No. 35. (available at www.maf.govt.nz).

McGREGOR, R.C. 1973. The emigrant pests. A report to Dr. Francis Mulhern, Administrator, Animal and Plant Health Inspection Service. Berkeley, California. 167 p. (Unpublished report on file at Hawaii Department of Agriculture, Honolulu, Hawaii.) (http://www.hear.org/articles/mcgregor1973.pdf, accessed October 2003)

MEYER, J.-Y. 1996. Status of *Miconia calvescens* (Melastomataceae), a dominant invasive tree in the Society Islands (French Polynesia). Pacific Science 50:66-76.

MEYER, J.-Y., and J. FLORENCE. 1996. Tahiti's native flora endangered by the invasion of *Miconia calvescens* DC. (Melastomataceae). Journal of Biogeography 23:775-781.

MEYER, J.-Y. 2003. Parks in peril in the islands of French Polynesia. Aliens 17:6.

MILLER, S.E., and L.G. ELDREDGE. 1996. Numbers of Hawaiian species: supplement 1. Bishop Museum Occasional Papers. 45:8-17.

MURRAY, J., E. MURRAY, M.S. JOHNSON, and B. CLARKE. 1988. The extinction of *Partula* on Moorea. Pacific Science 42:150-153.

NRDC/TNCH. 1992. The alien pest invasion in Hawaii: background study and recommendations for interagency planning. The Nature Conservancy of Hawaii and the Natural Resources Defense Council. Joint agency report. 123 p. (http://www.hear.org/articles/pdfs/nrdctnch1992.pdf, accessed October 2003)

O'DOWD, D.J., P.T. GREEN, and P.S. LAKE. 2003. Invasional 'meltdown' on an oceanic island. Ecology Letters 6:812-817.

OTA. 1993. Harmful non-indigenous species in the United States. U.S. Congress, Office of Technology Assessment. OTA-F-565. U.S. Government Printing Office, Washington, DC.

PASCOE, A. 2003. Red imported fire ant response stood down. Biosecurity 45:7.

SAVIDGE, J.A. 1987. Extinction of an island forest avifauna by an introduced snake. Ecology 68:660-668.

SPREP. 2000. Invasive species in the Pacific: A technical review and draft regional strategy, G. Sherley, technical editor. South Pacific Regional Environment Program. Apia, Samoa.

VEITCH, C.R., and M.N. CLOUT (eds.). 2002. Turning the tide: The eradication of invasive species. IUCN.

VINSON, S. B. 1997. Invasion of the red imported fire ant (Hymenoptera: Formicidae): spread, biology, and impact. American Entomologist, Spring 1997:23-39.

VITOUSEK, P.M., C.M. D'ANTONIO, L.L. LOOPE, M. REJMANEK, and R. WESTBROOKS. 1997. Introduced species: a significant component of human-caused global change. New Zealand Journal of Ecology 21:1-16.

WTO (World Trade Organization). 1998. Understanding the Sanitary and Phytosanitary Measures Agreement. (www.wto.org/english/tratop_e/sps_e/spsund_e.htm, accessed October 2003)