The Ecological and Socio-Economic Impacts of Invasive Alien Species on Island Ecosystems:

Report of an Experts Consultation

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**On behalf of the Convention on Biological Diversity &
The Global Invasive Species Programme**

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Contents

Executive Summary

Invasive alien species (IAS) and their effects on the environment, economy, and human health have captured the attention of scientists, natural resource managers, and policy makers worldwide. Article 8(h) of the Convention on Biological Diversity (CBD) calls on member governments to "as far as is appropriate: Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species," and calls for particular attention to be directed to geographically and evolutionarily isolated ecosystems, including islands. On behalf of the CBD and United States Agency for International Development (USAID), the Global Invasive Species Programme (GISP) convened a workshop in October 2002 to review the socio-economic and biological impacts of IAS on island systems. Experts from 10 countries, as well as GISP, the World Conservation Union (IUCN), and the World Conservation Monitoring Centre (WCMC) participated.

Participants in the Experts Consultation reached the following major conclusions: For biological and socio-economic reasons, islands are particularly vulnerable to bioinvasions. IAS can influence island environments at all levels of biological organization and also impact agriculture, fisheries, tourism, energy, water, and human health. Lack of access to extant technologies, particularly in small island developing States (SIDS) has resulted in IAS impacts that might have otherwise been avoided. While foreign aid can support IAS prevention and control efforts, it can also facilitate IAS introductions. Political pressure may exist to introduce IAS that will provide short-term economic benefits regardless of the longer-term biological costs. Although ballast water is a well-recognized pathway for marine bioinvasions, ship hull fouling by marine organisms is an often overlooked but significant pathway.

The following actions were recommended by the workshop participants: Develop informatics capacities to increase knowledge of and access to successful and cost-effective IAS prevention and management tools. Establish comprehensive IAS surveillance programs to enable early detection and rapid response. Undertake further assessments of IAS pathways and impacts, making the results widely available to resource managers and policy makers. Implement legal frameworks to minimize the risk of bioinvasion and develop alternatives to toxic anti-fouling agents.

The Ecological and Socio-Economic Impacts of Invasive Alien Species on Island Ecosystems: Report of an Experts Consultation

I. BACKGROUND

Invasive alien species (IAS) are non-native organisms that cause, or have the potential to cause, harm to the environment, economies, or human health. They are one of the most significant drivers of environmental change worldwide, consequently placing constraints on environmental conservation, economic growth, and sustainable development. IAS may also contribute to social instability and economic hardship. However, the costs to society greatly exceed those that can be measured in currency. They can also include unemployment, impacts on infrastructure, food and water shortages, environmental degradation, loss of biodiversity, increased rates and severity of natural disasters, illness, and lost lives.

The globalization of trade, travel, and transport is greatly increasing the diversity and number of IAS being moved around the world, as well as the rate at which they are moving. At the same time, changes in climate and land use are rendering some habitats more susceptible to biological invasions. In Article 8(h), the Convention on Biological Diversity (CBD) calls on member governments to "as far as possible and as appropriate: Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." However, national and international responses to the IAS problem have thus far been insufficient to counter their increasing toll on natural resources and society. One of the most significant barriers to policy development and implementation has been the paucity of reliable data on the biological and socio-economic impacts of IAS. Such information is desperately needed to convince decision makers of the scale of the problem and to enable stakeholders to determine the costs versus the benefits of their actions.

In March 2001, the Convention on Biological Diversity's (CBD) Subsidiary Body on Science, Technology, and Technological Advice (SBSTTA) recommended (VI/5) to the sixth Conference of Parties (COP 6) that the CBD initiate assessments on the impacts of IAS. This recommendation was based on a desire to advance assessments on current priority issues, and to test a range of methods and modalities for assessments in accordance with paragraph (b) of decision V/20 (COP 5) and paragraphs 1 and 9 of recommendation VI/5 (SBSSTA 6).

As the International Thematic Focal Point for the CBD's Clearing-house Mechanism (CHM), the Global Invasive Species Programme (GISP) was contracted to lead this project and to work with Parties and other bodies. The project brief provided by the CBD Secretariat is contained in document UNEP/CBD/SBSTTA/7/3.[1]

In order to inform development of and identify case studies for the assessment, an *Expert Consultation on the Ecological and Socioeconomic Impacts of Invasive Alien Species on Island Ecosystems* (hereafter "Experts Consultation") was held under the auspices of the Global Invasive Species Programme (GISP) at the premises of the Hilton Hawaiian Village Beach Resort and Spa, Honolulu, Hawai'i, from October 18 to October 19, 2002. Seventeen individuals, with collective

[1] http://www.biodiv.org/doc/meetings/sbstta/sbstta-01/official/sbstta-07-03-en.doc.

expertise in island systems around the world, participated in the consultation. The complete list of participants is contained in Annex II.

II. REPORT OF THE MEETING

1. OPENING OF THE MEETING

1.1 Professor Richard Mack, Co-chair of the GISP Evaluation and Assessment Working Group and Chair of the Experts consultation, called the meeting to order at 8:30 a.m. on 18 October 2002. He opened the meeting by thanking the coordinators and sponsors of the Experts Consultation, as well as the attendees for accepting the invitation to participate. Professor Mack said that the assessment of the biological and socio-economic impacts of IAS on islands (hereafter "Islands Assessment") was the first of four ecosystem-based assessments that GISP will be undertaking on behalf of the CBD. Professor Mack then introduced Dr. Jamie K. Reaser, Executive Director of GISP, as meeting Facilitator and Dr. Laura Meyerson, Coordinator of GISP's Evaluation and Assessment Working Group, as Rapporteur.

Dr. Reaser welcomed and thanked the participants and provided an overview of the Islands Assessment project, as well as the agenda for the Experts Consultation.

2. OBJECTIVES OF THE EXPERT CONSULTATION

2.1. Dr. Reaser explained that the CBD requested that GISP, as an International Thematic Focal Point for the CHM, assess the ecological and socio-economic impacts of IAS on island ecosystems. The request came as response to paragraph 6 (d) of SBSTTA recommendation VI/5 in which the decision was made, in accordance with paragraph 29 (b) of decision V/20 and paragraphs 1 and 9 of VI/5, to initiate assessments on the impacts of invasive alien species (IAS). The report arising from the assessment will also supports decision VI/23 of the Conference of Parties (COP) which urged research and assessments on the causes and consequences, as well as the prevention and management, of invasion alien species (IAS)[2]. The Expert Consultation is being convened in order to identify the expertise and information necessary for the Islands Assessment.

2.2. According to Dr. Reaser, the primary outputs of the Islands Assessment will include a 15-page summary of the biological and socio-economic impacts of IAS on island ecosystems (Information Document) and a review article for publication in a refereed journal.

3. GENERAL INTRODUCTION TO THE ISSUE OF INVASIVE ALIEN SPECIES ON ISLAND ECOSYSTEMS

3.1. The Chair invited participants to provide brief case studies that illustrated both the ecological and socio-economic impacts of IAS on specific ecosystems and/or island ecosystems. Dr. Quentin Cronk (University of British Columbia) reported on several of the socio-economic and cultural drivers that have led to species introductions in several island ecosystems, the ecological impacts of the subsequent invasions, and outlined the five stages in the trajectory of a biological invasion. Dr. Lucius Eldredge (Pacific Science Association, Bishop Museum) reported on marine invasions in Hawai'i. Dr. John Mauremootoo (Mauritian Wildlife Foundation) reported on terrestrial invasions in Mauritius. Dr. Dennis O'Dowd (Centre for Analysis and Management of Biological Invasions) reported on the impacts of the yellow crazy ant (*Anoplolepis gracilipes)* invasion on Christmas Island. Mr. Sigurdur Thrainsson (Ministry for the Environment, Iceland) reported on biological invasions in Iceland. Dr. Moses Kairo (CAB

[2] http://www.biodiv.org/doc/meetings/sbstta/sbstta-01/official/sbstta-07-03-en.doc

International) reported on biological invasions in Caribbean Island ecosystems. Ms. Leliua Vaiutu (Department of Agriculture, Tuvalu) reported on IAS in Tuvalu.

3.2. Each speaker was asked to address the following points during their presentation:

- What are believed to be the major biological and socio-economic impacts of IAS on island ecosystems?
- What variables (e.g., island history, ecotypes, island size and distance, pathways, climate, region of the world, etc) are believed influence the impacts of IAS on island ecosystems?
- What are the "best practice" measures for the prevention, eradication, and control of IAS in island ecosystems? How do the principles/practices differ from continental systems?

Dr. Cronk addressed the historical and cultural links between mainland countries and islands that have contributed to many biological invasions:

- The wet evergreen forest of Madeira Island, Portugal contains a high degree of endemism of great biological interest. Because it is a Portuguese island, Madeira has strong social and socio-economic connections to Portugal, and many plants, such as the sycamore maple (*Acer pseudoplantanus*), have been introduced from Europe into the Madeiran "laurisilva."
- Saint Helena, a United Kingdom dependent territory, was an important coaling station for steam ships when they went around the Cape of Good Hope between Britain and India. After the opening of the Suez Canal in 1869, St. Helena's role as a coaling station diminished and the island was therefore in need of another industry. St. Helena began producing brown string for wrapping parcels. Native forest was cut down to plant introduced New Zealand flax (*Phorium tenax*). By the 1950s, demand for the flax string declined and the industry collapsed. The abandoned flax plants continued producing abundant seed which germinated on native tree ferns and spread rapidly, invading surrounding areas by up to five meters per year.
- Mauritius, a British island off the coast of Africa, promoted species introductions in an attempt to increase land productivity. A high rate of biological invasion resulted. In contrast, Socotra Island in the Indian Ocean was never colonized by a European power. It remains relatively unaltered by humans, perhaps because of its dry climate, but more likely because it has not had the socio-economic factors driving the invasion.
- Five different stages make up the invasion trajectory of an introduced species: (1) introduction, (2) naturalization, (3) facilitation, (4) invasive spread, and (5) stabilization and control. For woody plants, a typical invasion trajectory can take 100-200 years to proceed through all of the stages. At each stage of the invasion trajectory, different factors are important. Unfortunately, most invasions are not detected until stage 4, the exponential growth phase, rather than stages 1-3. As a result, there is little information on how to bring the population curves down and decrease growth and spread. Therefore, it is important to identify means to stop invasions in their introductory stages, to control established invasives, and to effectively address the socio-economic and cultural factors that are driving the invasions.

In summary:

- Both cultural links and socio-economic factors are important drivers in biological invasions.
- Invasions should be addressed according to where they fall along the invasion trajectory.
- Characterization of cultural drivers and individual invasion trajectories will provide key insights how to address biological invasions.

Dr. Lucius Eldredge discussed marine invasions, particularly in Hawai'i.

- Approximately 20% of Hawaiian biota is introduced. Of these, approximately 70% of the introduced species establish. Approximately 7% of the marine invertebrates are IAS. In Waikiki harbor, 7% of the species are IAS, but two species (i.e., *Gracilaria salicornia* and *Hypnea musciformis*) are causing the majority of the problems. The only introduced echinoderm in Hawai'i is the sea star (*Asterias amurensis*).
- In marine ecosystems the following criteria usually indicate that an organism is an IAS: sudden appearance of the organism, the presence of an artificial substrate, and association with a dispersal mechanism and/or other IAS. Species of uncertain origin are termed cryptogenic species.
- Surveys in Hawai'i indicate that the number of IAS present decrease sharply outside of the harbor.
- The majority of the shipping routes in the Pacific go through Hawai'i, making Hawai'i a major recipient of IAS. Hull fouling is a greater problem in terms of IAS introductions than ballast water in Hawai'i, and likely in Pacific island insular systems as well. For example, approximately 80% of the introduced marine invertebrates in Hawai'i result from hull fouling.
- Intensive biological inventories need to be undertaken in marine ecosystems along with anecdotal observations and reports. A global core team of taxonomists has been developed to assist in identification of unknown marine species. Voucher specimens should be deposited in the appropriate museums to aid in species identification.
- An increase in introductions from hull fouling is expected as a result of the ban on TBT (tributylin), a toxic ship hull coating. Military and commercial ships have few problems with hull fouling because they are cleaned regularly.
- Most industries that utilize marine IAS are not economically important, with the exception of (*Kappaphycus* spp.) which serves low-income communities. The major economically relevant near-shore industries are recreation and tourism. Currently the primary impacts due to IAS in Hawai'i are to biodiversity and aesthetics, although the mud blister worm (*Polydora websteri*), which can establish in cement tanks, put the oyster industry out of business.

Dr. John Mauremootoo reported on terrestrial invasions in Mauritius.

- Four islands form Mauritius: Reunion, Mauritius and Rodrigues, and Round Island. The differences in the topography and the individual island's history largely determine the extent to which they have been invaded.
- Mauritius has a high degree of endemism. For example, 70% of flowering plants, 80% of birds, and 90% of reptiles are endemic.
- Species extinctions occurred on Mauritius prior to the influence of habitat destruction. Shipwrecks introduced cats and rats to Mauritius even before the main island was settled. Thus, as much as 20% of the native species may have disappeared prior to human settlement.
- Natural disturbances, cyclones in particular, have a major influence on the ecosystem. The native trees in Mauritius are very resilient to this disturbance, but the presence of IAS increases disturbance impacts, such as soil erosion.
- Dramatic changes can occur in an ecosystem following biological invasions. For example, following human settlement and introduction, fire climax species may replace native species and completely changing soil erosion, nutrient cycling, and altering species dominance.

- Rodrigues island was meant to become a productive “grain basket,” but this effort failed. Reforestation was attempted with introduced eucalypts (*Eucalyptus*, spp.), but has resulted in a water shortage.
- Reunion is still forming via lava flows and 30% of its native forest remains, allowing recruitment of native species. On the island of Mauritius, recruitment of native species is low, and does not occur on at all on the island of Rodrigues.
- Restoration of native canopy cover decreases light in the forest understory and helps to prevent IAS incursions. IAS control measures occur primarily in the conservation management areas. Active restoration efforts are occurring on Ile aux Aigrettes and Round Island. Future plans for control of IAS include moving to larger scale management programs (>100 hectares). This might include introductions of non-native tortoise species to replace the functional role of the now extinct Mauritian giant tortoise in the ecosystem. In the short-term, temporary introductions of other herbivores, such as goats, may be necessary to clear out vegetation.
- There are no indigenous people of Mauritius, and colonization was relatively late, involving three different countries (i.e., Dutch, followed by the French who were responsible for most of the introductions, and then the British who continued introducing species). Therefore, a mentality of exploitation exists on the islands and there is little knowledge of native species. This in turn affects attitudes toward conservation and restoration, and also means that IAS are generally not considered to be a problem. However, the small human population on Mauritius also means that virtually every person can be reached and educated on the issues surrounding IAS, making the long-term prospects for addressing this issue very good.
- The main industries of Mauritius (i.e., tourism, sugar, textiles, and off-shore banking), have thus far been little affected by IAS, but marine invasions pose a potential threat to the tourist industry.

Dr. Dennis O’Dowd reported on Christmas Island.

- Island ecosystems vary in numerous ways that affect the extent and impact of IAS. These include the size of the island (e.g., island continent, island chain versus single island), the extent of biodiversity and endemism on the island, the topography, the age of the island, and the extent of human influence.
- Christmas Island, south of Java, provides an example of many of the IAS problems facing other islands. Christmas Island has a high density of native red land crabs (*Gecaroidea natalis*), approximately 1 per square meter. These crabs live and burrow in the rain forest and migrate annually to the sea. The crabs are diurnal and omnivorous, but feed primarily on plant litter, and thus are the dominant consumers of rainforest detritus. An exclosure experiment revealed that excluding the crabs from the forest releases a large number of seedlings and detritus accumulates on the forest floor. Clearly, the crabs have a major influence on forest processes.
- Yellow crazy ants (*Anoploepsis gracilipes*) were accidentally introduced to Christmas Island between 1915 and 1934, but have spread rapidly over the last decade. This IAS is a polygamous tramp ant with generalized nesting habits and a broad diet. It is continuously active, a “three dimensional forager.” Another species, the lac scale insect (*Tachardina aurantiaca*), interacts symbiotically with the yellow crazy ant. This is a cryptogenic species (i.e., of unknown origin). These two species have significant negative impacts on the ecosystem in general, and on the land crabs in particular, causing what has become known as an “invasional meltdown.” The ants kill the crabs by spraying them with formic acid. When the crabs are extirpated, there is a substantial increase in the accumulation of litter on the forest floor, a result that is similar to the

exclosure experiments performed by the researchers. However, in this case it is playing out across the landscape, causing rapid ecosystem state changes. The scale insects produce sooty moulds over the leaves of forest trees, decreasing photosynthesis and thus tree survival. The ants collect honeydew and spit it out on the leaves, causing the scale population to explode and lowering the survival of the trees. The ants are also consumers of arthropods and vertebrates. Some data show that this is affecting the reproductive success of birds, which are important dispersers of fruits (e.g., the Christmas Island thrush, *Turdus poliocephalus erythropleurus*).

- An island-wide survey on Christmas Island was designed to assess the impacts of the ant invasion. The results identified the spatial scale and intensity of the invasion, allowing delineation of the treatment areas and estimates on impacts and treatment costs. “Supercolonies” (an aggregation of two or more ant colonies which can consist of individuals from distinct nests) were 22.7% of the invasion and a total of nearly 2500 ha were infested. To address this invasion, an aerial campaign of poisoned fishmeal granular bait (0.01% Fipronil) was used and dispersed at a cost of AUS$ 247,000. Monitoring of efficacy, non-target effects, and evaluation of broader application are currently underway.
- Some of the socio-economic factors on Christmas Island that are related to IAS include:
    - The presence of a detention center for political asylum seekers.
    - The presence of a space launch facility.
    - Issuance of new mining leases.
    - A nine-fold increase in shipping container traffic.
- The invasion trajectory for the yellow crazy ant was long, perhaps because of water stress or the more recent biotic facilitation by the cryptogenic scale helped the ant to become successful. It is unlikely that the red crab was itself introduced. The high density of crabs probably results from a lack of predation following the extinction of endemic rats at the turn of the 20th century.
- Eradication of the yellow crazy ant may be impossible since there are some areas in which the ants live in very low densities and because the non-target impacts of eradication might be unacceptable.

In summary:

- In simple systems, IAS can unleash complex and unexpected outcomes. For example, a single IAS can produce a rapid state change and new associations can amplify the impacts of each species or novel associations with other IAS could form.
- Immediate reporting of the impacts and assessments of IAS invasions are essential.
- Surveys, use of geographic information systems (GIS), and monitoring of control efforts are critical.
- The integration of science and policy is vital, and we need to ensure that all scientific studies are independent and transparent.

Mr. Sigurdur Thrainsson reported on invasive alien species in Iceland.

- Geologically, Iceland is a very young country (~13 million years old), and because it is volcanic, it is still being formed. When settled in 847 AD, Iceland had 65% vegetative cover and 25% forest cover; today, only 25% of the vegetation and forest cover remains. This decrease in vegetative cover largely occurred during the first 300 years of settlement. In general, Iceland is low in biodiversity, but has many species on the red data list.
- There are relatively few non-native species in Iceland, but IAS do present some of the most serious environmental problems. The worst IAS include the Nootka lupin (*Lupinus*

lepidus), the American mink (*Mustela vison*), rainbow trout (*Oncorhynchus mykiss)*, ruddy duck (*Oxyura jamaicensis)*, Sitka alder (*Alnus viridis*), green spruce aphid (*Elatobium abietinum*), plus hundreds of flowering plant species.

- The Nootka lupin, a nitrogen fixing plant species from Alaska, was intentionally introduced to Iceland to assist with land reclamation. Lupin exhibits different growth forms depending on latitude: in southern Iceland it grows tall and forms closed canopies, but in northern Iceland lower rainfall limits both height and density.
- In Iceland, lupin is considered to have both positive and negative qualities, and is therefore removed from some areas while being planted in others. Lupin facilitates land reclamation because it does not require fertilization and therefore reduces short-term costs, and also has potential pharmaceutical uses for cancer treatment. However, it also changes successional trajectories, decreases light to native plants, and can be difficult to control and therefore has recently been removed from national parks. Further removal efforts are being considered despite the fact that it is still intentionally seeded on bare gravel flats.
- Recent dialogues between the soil conservation service and the forest service have resulted in guidelines for lupin planting. The soil conservation service is also beginning to exploring the use of native species instead of lupin. However, because Iceland does not have another native species that is suitable to replace lupin for erosion control, its use may continue despite scientific evidence of its negative impacts on natural systems.
- American mink was imported to Iceland in 1931 for use by the fur industry. It escaped a year later and the first breeding den was found in 1937. In approximately 40 years, mink fully colonized the coastal areas of Iceland with the exception of glacial rivers killing seabirds and affecting their nesting distributions. Mink have caused the extinction of the water rail (*Rallus aquaticus*) and the Slavonian grebe (*Podiceps auritus*). Mink escape from fur farms and attack eider duck colonies on other farms, and negatively affect fish release projects. Hunting is currently a control measure, but this is having little impact on mink populations.
- The ruddy duck (*Oxyura jamaicensis*) was first imported to Britain from the U.S. and is now spreading to other countries, including Iceland. The first ruddy duck breeding attempts in Iceland were noted in 1990 and the first successful fledges occurred in 1994. Iceland eradicated ruddy ducks in 2002 because they destroyed the habitat of native bird species.

Experience in Iceland indicates that:

- Island size, distance from neighboring countries, frequency and magnitude of species introductions, as well as climate, all influence biological invasions and their impacts. Islands differ from continental systems in their isolation, easier border control, and the invasion pathways.
- More education and information on pathways is needed to prevent further introductions. In addition, prevention efforts must include border control, permits and/or fines for illegal species importation, as well as monitoring and research.
- Eradication efforts must include early detection and action in order to be successful. Control should be implemented if eradication is not possible.

Mr. Moses Kairo reported on IAS in the Caribbean

- The impacts of IAS on biodiversity and the ecology of the Caribbean are not widely recognized and little quantitative data on their effects exist. Instead, IAS are viewed mainly as a serious agricultural problem. However, IAS are increasingly becoming an environmental problem – in the last seven years at least six species have emerged as serious pests.

- New factors, such as the need to meet international accepted standards for trade under World Trade Organization (i.e., those associated with the International Plant Protection Convention) have placed greater emphasis on the threat of IAS.
- Disturbances such as habitat destruction or modification make small islands inherently more susceptible to IAS. The mesic climate favors establishment of IAS throughout the year. Primary biological impacts of IAS include displacement and competition between IAS and endemic species. Secondary biological impacts include soil erosion and flooding. However, some introduced species, such as those brought in for biological control, do produce beneficial impacts.
- IAS have had significant political consequences in the Caribbean. For example, it has been suggested that in Grenada the government in power at the height of the hibiscus mealy bug (*Maconellicoccus hirsutus*) infestation acted too slowly and that this contributed to its defeat in the subsequent election.
- There have been significant commercial income losses due to IAS impacts on agriculture and forestry as a result of trade embargoes. For example:
    - Grenada lost $18.3 million due to the Hibiscus mealy bug. Control costs exceeded one million dollars.
    - Trinidad and Tobago, Saint Vincent and the Grenadines reported millions of dollars (US) in losses related to IAS impacts on agriculture and forestry.
- Several socio-economic factors influence the extent of IAS impact in the Caribbean. Many islands have close cultural links and there is rapid movement of people and goods at the local, regional, and global level. Thus, IAS can spread quickly throughout the Caribbean such as the hibiscus mealy bug which spreads at a rate of 2-3 islands per year.
- Prevention (including quarantine exclusion) is the first line of defense against IAS, but has failed in multiple ways. On many islands there are inadequate resources for quarantine and the large number of potential entry points to the islands makes border security difficult. Relevant legislation may be out of date or non-existent. For example, in Curacao laws against importing harmful species are still under development, but in the meantime, agricultural produce and other organisms are brought in with little control. Because Curacao is a major travel hub, IAS established there are likely to spread.
- Cooperation between governments may be lacking. For example, a country could be infected with mealy bug but not politically acknowledge its presence and therefore fail to take any measures to prevent spread to other countries.

In summary:

- There is a lack of quantitative data on IAS in the Caribbean.
- IAS pose a major threat to biodiversity.
- The loss of income is the most significant socio-economic impact.
- Quarantine is the most important defense.
- Approaches to eradication and control do not differ from continental systems.
- Government commitments for long-term efforts to manage IAS are not currently guaranteed since changes in administration can interrupt efforts.

Ms. Leilua Vaiutu reported on IAS in Tuvalu

- Tuvalu is a small island nation in the Pacific made up of nine islands totaling 25 square kilometers. Forest covers approximately 67% of the land.

- Three of the major IAS in Tuvalu are the coconut scale insect (*Aspidiotus destructor*) which damages food crops (e.g., breadfruit [*Artocarpus altilis*], sweet potatoes [*Ipomoea batatas*]), and impacts both social and economic systems; the termite (*Neotermes rainbowi*), which topples coconut palms, and the pink mealy bug (*Macinellicocus hirsutus*), a pest of the food staple breadfruit.
- A biological control program exists for coconut scale. The Secretariat of the South Pacific (SPC) provides the control agents and they are released at the site of infestation. The agricultural department provides advice on how to treat pests and planting of resistant trees. The South Pacific Regional Environmental Programme (SPREP) also works closely with environment and the local government.

Tuvalu's needs include:

- Identification of non-native and native species.
- IAS survey results from other countries.
- Expert technical advice and facilities for IAS identification.

4. CONCLUSIONS AND RECOMMENDATIONS

Following the presentations, the facilitator led the participants through a discussion based on the questions listed below. In addition to the summaries provided below, a list of the main points and issues arising from the presentations and follow up facilitated discussions is contained in Annex V:

- What case studies (data) exist to document the impacts of IAS on island ecosystems and through whom can this information be obtained?
- What gaps in knowledge exist and how might these gaps be filled? [gaps in knowledge, opportunities for filling gaps]
- What can be accomplished in an assessment of the impact of IAS on island ecosystems in 9-months? [goals]
- What are the steps to undertaking a 9-month assessment (including timeline)? [timeline]
- Who needs to be involved in the assessment and how? [contributors – roles and responsibilities]
- What are the first steps and who will take them?

4.1. What case studies (data) exist to document the impacts of IAS on island ecosystems and through who can this information be obtained?

The following brief summary case studies with cited references can be found in Annex I of this document. These include contributions from participants and other stakeholders.

- *Miconia calvescens*: a major threat for tropical island rainforests.
- Introduced mangroves in the Hawaiian Islands.
- Invasive species and coral reefs.
- *Achatina fulica*, the giant African snail and *Pomacea canaliculata*, the golden apple snail
- *Salvinia molesta* in Sri Lanka.

Additional resources suggested by meeting participants included eight papers on coral reef non-indigenous and invasive species resulting from a symposium of the same name held at the Bali International Coral Reef Symposium held August 27, 2000. These are now available on the web at: http://www.bishopmuseum.org/research/pbs/coralreefsymp.html.

The following paper was suggested:

Howarth, F. G., G. Nishida, and A. Asquith. 1995. Insects of Hawai'i. In E.T. LaRoe, ed., *A report to the nation on the distribution, abundance and health of U.S. plants, animals, and ecosystems.* U.S. Department of Interior, National Biological Survey, http://biology.usgs.gov/s+t/noframe/t068.htm.

Information on biological control of *Cactoblastis* in the Caribbean can be obtained from Bob Pemberton, USDA ARS biocontrol (bobpem@saa.ars.usda.gov). Additional information and case studies can be found among the papers listed in the attached bibliography, Annex IV.

4.2 What gaps in knowledge exist and how might these gaps be filled?

The following summary arises from the facilitated discussion. It does not represent an exhaustive list of the gaps in knowledge and potential responses, but a list of gaps in information that meeting participants believe to be a priority for research and other actions.

Issue: Prevention, early detection, and rapid response are widely accepted as the best ways to safeguard islands from IAS impacts. However, a lack of public education on IAS issues, poor cooperation between countries, a substantial lack of trained personnel to identify and intercept IAS at country borders, and few, if any, mechanisms to respond to nascent outbreaks of IAS present significant obstacles. Furthermore, lack of ecological and taxonomic information limits the ability to predict the impacts of IAS or even simple identification of species as introduced or native to an area.

Response: Build capacity to prevent and respond to IAS introductions in the following ways:

- Raise awareness of the biological and socio-economic impacts of IAS by educating governments, local communities, relevant industries, and tourists. These sectors are often the first line of defense in preventing or predicting a biological invasion.
- Apply methodology from social science research in order to identify community values and ways of involving communities in the IAS issue.
- Engage trade related bodies (e.g., World Trade Organization) in island IAS issues.
- Deposit voucher specimens in appropriate museums to assist with species identification.

Issue: Ballast water is recognized as a global pathway for IAS transport. However, the fouling of marine organisms on ships and other mobile structures is another significant invasion pathway that requires greater attention.

Response: Hull fouling must be considered a high priority by policy makers, natural resource managers, relevant industries, and investigators. The following steps should be undertaken:

- Support and undertake studies of fouling as an invasion pathway, as well as evaluating the biological and socioeconomic impacts of fouling organisms on marine ecosystems.
- Develop and enact best management practices and policies to physically clean ships hulls and marine equipment so as to minimize the risk of transport of fouling organisms.
- Develop environmentally sound alternatives to the toxic anti-fouling agents that are gradually being removed from use.
- Develop surveillance programs for detection and penalties for "polluters" who introduce IAS via fouling.

Issue: Relatively little quantitative data are available on the impacts of IAS on island ecosystems. At present there are no adequate tools to predict which introductions will produce successful invaders, or even quantitative and qualitative data on which introductions fail and why. This uncertainty poses considerable difficulty for policy-makers.

Response: Greater quantification will lead to better decision prevention policy. The following steps need to be taken:

- Conduct research on how to incorporate stochastic processes important in the early stages of invasion into population models. Better population models may lead to more successful predictions of which species introductions will become IAS.
- Improve knowledge of invasion risk and patterns of spread in order to prioritize species risk and reduce uncertainty by collecting higher quality data and improving modeling. In particular, identify the minimum thresholds for the initial population size of an introduction in order for an invasion to succeed.
- To predict and prevent future invasions, pathways for the introduction of species to island ecosystems must be identified. This is one of the most important measures that can be taken; therefore, more information is needed to develop tools to identify pathways.

Issue: A general assessment of the impacts of IAS on islands is difficult since there is little quantitative data is widely available. Experiments can be difficult to conduct on hard to access islands. Consequently, experimental data is often lacking and contributes to conservation failure in managing IAS on islands.

Response: Islands have limited resources, making the protection of ecosystem services particularly important. Because the science of identifying and quantifying ecosystem services is in its infancy, better methods are needed. Therefore, the following research should be facilitated:

- Quantify ecosystem services on islands to improve prediction of invasions, to prioritize actions, and to better understand IAS impacts.
- Conduct more ecological experiments, in the form of perturbations, field trials or adaptive management.
- Conduct research to enhance understanding of how exogenous factors (e.g., climate change, physical disturbance) exacerbate the impacts of IAS.
- Determine whether a lag phase exists for the realization of IAS impacts (i.e., while it is understood that some IAS undergo a lag phase prior to becoming invasive, is there also a lag before impacts of an invasion become apparent?)
- Conduct more research to understand how biological invasions on islands differ from continental invasions.
- Conduct complete biological inventories on island ecosystems, particularly on small islands. Despite islands having small and tractable biotas, most bioinventories are far from complete, particularly for invertebrates. On islands, more than on any other system, complete bioinventories are achievable.
- Consider bioinventories from IAS source regions (for little known invertebrate groups in particular) to aid understanding of pathways of invasion.

Issue: The introduction of IAS into new ecosystems can lead to the formation of novel biological associations. Several examples exist such as association of West Nile virus and Asian tiger mosquitoes (*Aedes albopictus*) in the United States. In most cases, these novel associations have not been predicted and little is known about the impacts of the species-species and species-environment interactions.

Response: Include the formation of novel biological associations in risk evaluations for species introductions. While these associations are by definition new and therefore unpredictable, indicators and predictive capacity should be sought.

4.3 What can be accomplished in an assessment of the impacts of IAS on island ecosystems in nine months? What do we want to encapsulate as the main message to get across?

Participants agreed that the biological and socioeconomic impacts of IAS on island ecosystems are increasingly large and significant problems that warrant serious attention. They believed that nine months provided a relatively short period of time to address these issues. Therefore, they recommended that attention be focused on the most pressing issues and on those areas where progress can be made to stop or mitigate invasions and their impacts. They believed that the following points must be conveyed through the assessment: IAS impacts cut across ecological, social and economic sectors and the impacts can be rapid, acute, chronic, and cryptic with long-term cascading effects. However, invasions are potentially manageable and their effects may be reversible in some cases. Prevention is the first line of defense. This can best be addressed through capacity building, sharing resources, and through networking and partnerships. For example, sharing biological control agents across countries or regions may produce significant cost savings.

4.4 Who needs to be involved in this process and how?

IAS affect all sectors of society. Participants recommended that case studies be used to reflect the linkages to stakeholders in industry, government, the health sector, agriculture, environmental sector, non-profits and local communities, as well as the news media.

4.5 What are the first steps and who will take them?

Participants recommended that the following steps be undertaking immediately following the meeting: 1) compile the summary information and 2) collect relevant case studies. Deadlines and a process were established for contributions and reviews of the documents.

5 PRODUCT ORIENTED MEETING PRODUCTS

Participants identified a series of actions that they wished to take as a group before the close of the meeting. They then divided into four working groups and produced the following documents. These products are included in this report in Annexes VI through IX.

- Press Release Prepared at the Islands Assessment Workshop October 19, 2002: Action Against Aliens on Islands Planned
- Fouling of Marine Ecosystems by Invasive Alien Species: A Call to Action
- Research needs: Invasive Alien Species on Islands
- Draft outline for information document and peer-reviewed manuscript

6 CLOSURE OF THE MEETING

After concluding remarks by the meeting Chair and the Facilitator in which they thanked the donors and the organizers of the meeting and the participants for their efforts and most valuable contribution, the Expert Consultation was declared closed by the Chairperson at 4 p.m. on Saturday, 19 October 2002.

Annex 1: Case Studies

Miconia Calvescens: A Major Threat for Tropical Island Rainforests

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Miconia (*Miconia calvescens*) represents one of the most dramatic cases of a documented plant invasion in tropical islands. Its extensive spread on several islands in French Polynesia and Hawai'i poses a major threat to the native rainforests and the unique terrestrial plant diversity of those islands.

Miconia, also known as *M. magnifica* in horticulture, belongs to the melastome family which contains some other invasive plants in tropical islands, such as Koster's curse (*Clidemia hirta*) in Hawai'i, Fiji, and La Réunion Island; (*Ossaea marginata*) in Mauritius; (*Memecylon caeruleum*) in the Seychelles; and princess flower (*Tibouchina urvilleana*) and glorybush (*T. herbacea*) in Hawai'i. *Miconia* is a small to medium sized tree, up to 16 m tall, whose large attractive dark-green leaves have purple undersides. It is native to Central and South America where it grows at elevations up to 1800 m as an under story species in tropical rainforest. It is reported as uncommon in its native range, and mainly found on riverbanks, along trails, at forest edges, and as a colonizer of small gaps.

It was introduced as a garden ornamental to Tahiti (Society Islands) in 1937, and was not recognized as a problem until the early 1970's when U.S. and French botanists first documented its invasiveness. Today, *Miconia* is present over 70% of the island of Tahiti (more than 70,000 ha) and found in all the mesic and wet habitats between 10 m and 1300 m elevation, including the montane cloud forest, where it forms dense monospecific stands. In Tahiti, *Miconia* is directly endangering 40 to 50 endemic plants by overtopping, shading, and crowding them. Terrestrial rare endemic orchids belonging to the genera *Calanthe*, *Phaius*, and *Moehrenhoutiana*; shrubby understory species belonging to the genera *Ophiorrhiza* and *Psychotria* (Rubiaceae), *Cyrtandra* (Gesneriaceae), and *Sclerotheca* (Campanulaceae: lobelioidae), as well s small trees such as *Fitchia* (Compositae), *Meryta* (Araliaceae) and *Myrsine* (Myrsinaceae), are among the most vulnerable. On steep slopes, pure stands of *Miconia* promote landslides and increase soil erosion.

The "Green Cancer," as it is popularly called in Tahiti, has also spread to the neighbouring islands of Moorea, Raiatea and Tahaa (Society Islands) and more recently to Nuku Hiva and Fatu Hiva in the Marquesas with soil contaminated by seeds. *Miconia* is also invasive in the Hawaiian islands (Hawai'i, Maui, Oahu and Kauai) where it was first introduced in the early 1960's as an ornamental, and now considered as the highest priority for control and eradication.

A number of ecological and biological characteristics make the species particularly competitive. It grows rapidly, up to 1.5 meters per year, and is adapted to low-light conditions. It flowers after 4-5 years of vegetative growth, and self-pollinates. Panicles of fleshy berries (up to 500) are produced and contain up to 230 seeds. There are at least three flowering and fruiting seasons per year. A single isolated tree has the capacity to produce millions of seeds annually. Fruits are eaten by frugivores (especially the introduced silvereye, *Zosterops lateralis*, and the red-vented bulbul, *Pycnonotus cafer*). Seeds are actively dispersed over long distances. The large soil seed bank (up to 50,000 seeds per square meters) can persist more than eight years, giving Miconia a formidable reservoir of regenerative capacity even if all plants are removed from an area.

Active control efforts have been conducted in the Hawaiian Islands and in French Polynesia since the early 1990's. In French Polynesia, a governmental inter-agency effort has been mobilized on the island of Raiatea (Society Islands) where small (350 ha) well-localized and accessible Miconia populations were first discovered in 1988. A total of about 1,220,000 plants including 1190 reproductive trees were destroyed between 1992-2002 during control and public education campaigns using hundreds of volunteers (schoolchildren, nature protection, religious groups, and the French army). The spread was checked on that island but eradication was not attained as new reproductive trees and small isolated populations were found during helicopter and ground searches.

A biological control fungal agent (*Colletotricum gloeosporioides* f. sp. Miconiae), discovered in Brazil in 1996 was tested for host-specificity and then first released in the Hawaiian Islands in 1997. It causes the development of necrotic leaf spots, followed by premature defoliation. The *C. gloeosporioides* was released in two test-zones of Tahiti in 2000 and 2002, and monitoring of its impact on *Miconia* and its dispersal is in progress. Other natural enemies (especially insects) are currently being sought in Costa Rica.

Miconia is known to be naturalized in the rainforests of Sri Lanka, and is spreading on the margins of north Queensland rainforests in Australia where it is considered a serious potential threat. Plants were also reported to be naturalized in Jamaica and to grow in the wild in Grenada (Lesser Antilles) and New Caledonia. The recent discovery of *Miconia* on the tropical island of La Réunion Island (Indian Ocean) as a planted ornamental is alarming. All island countries need to be vigilant in preventing the possible introduction of *Miconia*, one of - if not the most - damaging plant invaders of native rainforests in tropical islands.

Introduced Mangroves in the Hawaiian Islands: Their History and Impact on Hawaiian Coastal Ecosystems

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Due to extreme isolation and young geologic age, the Hawaiian archipelago has no native mangrove genera. In 1902, seven species of mangroves were procured from Florida and planted on the southwestern coast of Molokai by the American Sugar Company to stabilize the shoreline and provide forage for bees (MacCaughy 1917, Degener 1940, 1946; Wester 1981; Allen 1998). In 1922, approximately 14,000 mangrove propagules, including *Bruguiera sp*., were introduced to Oahu from the Philippines. Three of the original introduced mangrove species (*Rhizophora mangle*, *Bruguiera* sp. from the Philippines, and *Conocarpus erectus* from Florida and the Bahamas) have proliferated, but only *R. mangle* maintains abundant populations on all the main Hawaiian islands (Wester 1981, Allen 1998). *Bruguiera* sp. persists on Oahu and *C. erectus* occurs sporadically on Oahu, Lanai, and Maui (Wagner et al. 1990, Allen 1998). Currently in Hawai'i, mangroves inhabit large portions of low-energy coastlines (e.g., the lagoons of south Molokai, Kaneohe Bay, and Keehi) as well as the banks of streams and drainage channels (e.g., in Pearl Harbor and along Ala Wai Canal) (Allen 1998). Primarily due to its high dispersal capabilities, broad tolerance, and few natural enemies in Hawai'i, *R. mangle* has become the most abundant mangrove species and predominates along the seaward side of fringing forests (e.g., Wester 1981, Allen 1998, Cox and Allen 1999, Steele et al. 1999). Mangrove habitat appears to be expanding rapidly in Hawai'i, although data on the current rates of expansion of the larger mangrove forests (e.g., that on southern Molokai) are not well documented.

Mangroves have had a negative impact on indigenous Hawaiian fauna (Allen 1998, Cox and Allen 1999, Steele et al. 1999, Drigot 2001), and have altered coastline hydrodynamics and patterns of near shore sedimentation (Allen 1998). Mangroves in Hawai'i provide a habitat for exotic marine species such as the crab *Scylla serrata*, the barnacles *Chthamalus proteus* and *Balanus reticulatus*, and the fish *Oreochromis* sp. and *Poecilia* sp. (Demopoulos and Smith unpublished data). Mangroves are also colonized by other root encrusting and sediment-dwelling fauna, including a variety of sponges and polychaete species.

But more unfortunately, the introduction and spread of mangroves throughout the islands has led to habitat loss for the Hawaiian stilt (*Himantopus mexicanus knudseni*) and other wetland birds including the Hawaiian coot (*Fulica americana alai*) and Hawaiian duck (*Anas wyvilliana*) (Allen 1998, Cox and Allen 1999, Rauzon and Drigot 2002). This continued habitat loss is being mitigated by restoration of wetland refuges for both native and migratory bird species (e.g., Nuupia Ponds Wildlife Management Area, Kaneohe Bay; Cox and Allen 1999, Drigot 2001). As part of the restoration effort, the U.S. Fish and Wildlife Service plans to remove mangroves from the Waiawa Wildlife Refuge, located in Middle Loch, Pearl Harbor.

While mangroves reduce available bird habitat for migrants, the trees provide refuge for shorebirds from predators including the introduced mongoose (*Herpestes javanicus*) and rats (*Rattus norvegicus* and *Rattus rattus*). Despite mangrove removal and bird habitat restoration, little work has been conducted to evaluate the impact of mangroves and their removal on Hawaiian coastal communities. Preliminary data indicate that a rich group of organisms utilize mangrove habitat. However, it appears that most organisms do not use mangroves as a food source (Demopoulos and Smith, unpublished data). Thus, there is a great deal to learn about the food web and community structure of these mangrove systems. The continued presence of mangroves in Hawai'i provides scientists with the opportunity to investigate the impact of a highly invasive opportunistic plant on coastal ecosystems, including the role of mangroves in reducing coastal erosion and enhancing water quality.

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Achatina Fulica: the Giant African Snail[1]

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The giant African snail (*Achatina fulica*) species has been introduced widely, both deliberately (e.g., for food; Clarke *et al*. 1984) and accidentally. Characteristically, its populations may remain relatively low and more or less innocuous for some time, and then explode dramatically, with the snails becoming both agricultural and garden pests, threats to human health, as well as a public nuisance. In Hawai'i, as with many IAS, however, their populations subsequently decline to a low level (e.g., Eldredge 1988), for reasons that are not understood, although disease has been strongly suggested (Mead 1979, Waterhouse and Norris 1987, Cowie 1992).

Large population sizes and invasion of native ecosystems result in impacts such as eating native plants, modifying habitats, and likely out-competing native snails (e.g., Tillier 1992). However, the more insidious conservation problem is that they tempt agricultural officials to initiate a number of putative biological control measures. The best publicized is the introduction of predatory snails, most notably *Euglandina rosea* (see below). The first attempts at such biological control were made in Hawai'i. Fifteen carnivorous species were deliberately introduced (Cowie 1998a). Of these, nine did not become established; the fate of three is unknown but they are certainly not common and do not appear to be causing serious problems. However, three have become established and are discussed below: *Euglandina rosea*, *Gonaxis kibweziensis*, *G. quadrilateralis*. There is no scientific evidence that the predatory snails are the reason for the decline in numbers of *A. fulica* (Christensen 1984).

Similar ill-conceived attempts at biological control involving *Euglandina rosea* in particular have been implemented in French Polynesia, American Samoa, Guam, and a number of other places in the Pacific and Indian Oceans (Griffiths *et al*. 1993) (see below under *Euglandina rosea*).

In addition to the deliberate introduction of predatory snails, the predatory flatworm *Platydemus manokwari* has also been introduced, although as yet less widely (Eldredge 1994a, 1995). It is reported that this flatworm can indeed cause populations of *Achatina fulica* to decline (Muniappan 1983, 1987, 1990; Muniappan *et al*. 1986; Waterhouse and Norris 1987), but the evidence is only correlative, not convincingly causative. However, the flatworm has also been implicated in the decline of native species on Guam (Hopper and Smith 1992). The flatworm has been seen in Hawai'i (Eldredge 1994a, 1995) but as yet does not appear to be present in large numbers (M.G. Hadfield, unpublished observations).

These introductions of putative biological control agents against *A. fulica* are extremely dangerous from the perspective of the conservation of native snail species. And in any case, there is no good evidence that they can control *A. fulica* populations.

Achatina fulica continues to spread both intentionally and accidentally; for instance it was first reported on ‘Upolu (Samoa) in 1990 and in Kosrae (Federated States of Micronesia) in 1998. Some islands remain free of it, such as Ofu (American Samoa), yet seriously at risk. Once established on one island of an archipelago, the risk of local dispersal to other islands in the group is very high (Waterhouse and Norris 1987). People still see *A. fulica* as a potential food source. An effort has been made to promote it as a food resource on ‘Upolu as a method of controlling them. However, promoting a pest, for whatever seemingly positive reason, seems fundamentally counterproductive, as it will likely encourage the further deliberate spread of the snails around the island and possibly into other regions.

History of A. fulica introductions

Hawaiian Islands.

Kaua‘i - 1958 (Mead 1961); O‘ahu - 1936 (Mead 1961); Moloka‘i - 1963 (Mead 1979); Maui - 1936 (Mead 1961); Länaʻi - 1963-1972 (Mead 1979; possibly not established); Hawai‘i - 1958 (Mead 1961).

French Polynesia.

Marquesas Islands: Nuku Hiva, Hiva Oa - before 1984 (Pointier and Blanc 1984).

Society Islands: Tahiti - 1967 (Mead 1979); Moorea, Huahine, Raiatea, Tahaa, Bora-Bora - after 1967 but before 1978 (Clarke *et al*. 1984; Mead 1979).

Tuamoto Archipelago: Moruroa - 1978 (Mead 1979); Hao - 1978 (Mead 1979); Apataki - (Pointier and Blanc 1984).

Samoa.

‘Upolu - 1990 (Cowie 1998c).

American Samoa.

Tutuila - 1977 (Cowie 1998c); Ta‘ü (Eldredge 1988, Cowie 1998c).

Wallis and Futuna.

Wallis Islands - (Anon. 1998a).

Tuvalu.

Vaitupu - 1996 (Anon. 1996a, b; eradicated).

New Caledonia. 1972 (Gargominy *et al*. 1996; Mead 1979).

Vanuatu.

Efate - 1967 (Mead 1979); Espiritu Santo - (Mead 1979).

Solomon Islands. (Anon. 1999).

Papua New Guinea. pre-1945 (Mead 1961; Dun 1967).

Port Moresby - early 1960s (Mead 1979); Lae - 1976-1977 (Mead 1979); Madang - before 1972 (Mead 1979); Bougainville - 1970 (Mead 1979); Bismarck Archipelago (New Britain, New Ireland) - pre-1945 (Mead 1961); Manam Island - (Lambert 1974).

Marshall Islands.

Kwajelein - (Anon. 1996, 1998a).

Federated States of Micronesia.

Kosrae: 1996 (Anon. 1998a).

Pohnpei: 1938 (Mead 1961, 1979; Smith 1993b).

Truk - (Mead 1979; Smith 1993c): Dublon - pre-1940 (Mead 1961); Moen, Romonum - pre-1945 (Mead 1961); Uman, Fefan - 1948 (Mead 1961).

Belau (Palau).

Babeldaob - 1938 (Mead 1961; Cowie *et al*. 1996); Oreor (Koror) - 1939 (Mead 1961); Ngerekebesang (Arakabesan), Ngemelachel (Malakal) - pre-1950 (Lange 1950); Ulebsechel (Auluptagel), Ngeruktabel (Urukthapel) - 1949 (Mead 1961); Beliliou (Peleliu) - pre-1946 (Lange 1950); Ngeaur (Angaur) - pre-1950 (Lange 1950).

Guam. 1943 (Bauman 1996; Mead 1961; Eldredge 1988).

Northern Mariana Islands.

Rota, Tinian, Saipan - 1936-38 (Mead 1961; Bauman 1996); Aguijan - pre-1939 (Mead 1961); Pagan - 1939 (Mead 1961).

[1] This case study originally appeared in the following: Cowie, R. H. 2000. Non-indigenous land and freshwater molluscs in the islands of the Pacific: conservation impacts and threats. Invasive species in the Pacific: a technical review and draft regional strategy. South Pacific Regional Environment Programme. For complete citations please refer to this document at www.sprep.org.ws.

Family Ampullariidae[1]

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Ampullariidae are freshwater snails predominantly distributed in humid tropical and sub-tropical habitats in Africa, South and Central America and South-East Asia. They include the largest of all freshwater snails (*Pomacea maculata* can exceed 15 cm) and frequently constitute a major portion of the native freshwater mollusk faunas of these regions. Among the seven to ten genera usually recognized, the two largest are *Pomacea*, with about 50 species, and *Pila*, with about 30. Snails in these two genera in particular are frequently known as 'apple snails,' because many species bear large, round, often greenish shells. They have also become known as 'mystery snails,' 'miracle snails,' 'golden snails', among other common names ('kuhol' in the Philippines, 'bisocol' in the Filipino community in Hawai'i). The comprehensive review of Cowie (in press a) focuses on the increasing impact of ampullariids as agricultural pests, but also discusses their potential environmental impacts. Some species have been used to control aquatic plant pests such as water lettuce (Perera and Walls 1996). Many species appear to be extremely voracious and generalist in their food preferences and concern has been expressed (Simberloff and Stiling 1996) that they could seriously modify native ecosystems.

The genus *Pomacea* is centered in South and Central America, extending into the Caribbean and the southeast of the US. One or perhaps more species have been taken from their native South America to Southeast Asia to be cultured for food (Mochida 1991). The market for the snails never developed. The snails were released or escaped into the wild, becoming major pests in rice paddies (Cowie, in press a; Naylor 1996). Other species have been developed as aquarium snails (Perera and Walls 1996) and have been moved around the world via the aquarium trade.

Pomacea canaliculata **(Lamarck, 1804) -- golden apple snail**

This South American species seems to be the major pest (although there remains considerable taxonomic confusion regarding its true identity and whether there is more than one pest species; Cowie, in press a). It was originally introduced from South America to southeast Asia around 1980, as a local food resource and as a potential gourmet export item. The markets never developed; the snails escaped or were released, and became a serious pest of rice throughout many countries of south-east Asia (Cowie, in press a; Naylor 1996). They were introduced to the Hawaiian Islands in 1989, probably from the Philippines, and for the same reasons as for their initial introduction to south-east Asia. Again, they rapidly escaped or were released and quickly became a major pest of taro (Cowie 1995a, 1997).

P. canaliculata reproduces extremely rapidly and appears to be a voracious and generalist feeder (Cowie, in press a), although experimental results suggest that it does nevertheless have some strong food preferences, particularly an aversion to a major aquatic plant pest, water hyacinth (*Eichornia crassipes*) (Lach *et al*., in prep.). In the Hawaiian Islands it is spreading rapidly from taro-growing areas into native wetlands and other native freshwater systems where it is perceived as potentially having a serious impact (Lach and Cowie, in press). These potential impacts could involve destruction of native aquatic vegetation leading to serious habitat modification, as well as competitive and even predatory interactions with the native aquatic fauna, including native snails (Cowie, in press a; Simberloff and Stiling 1996). Already, introduced *Pomacea* have been implicated in the decline of native species of *Pila* in south-east Asia (Halwart 1994). Also, native species of *Pila* in the Philippines are reported to have declined as a result of extensive pesticide applications against introduced *Pomacea* (Anderson 1993).

At present, *P. canaliculata* is not widespread in the region (only the Hawaiian Islands, Guam, and Papua New Guinea). It has also probably been introduced to Belau (Palau) but was eradicated (Cowie, in press a). However, the lesson from south-east Asia is that people in some countries (e.g., Cambodia) have ignored the negative experiences of other countries (e.g., Vietnam, Philippines) and have persisted in trying to establish aquaculture operations, despite advice to the contrary (Cowie 1995b). They have then come to regret this course as the snails inevitably escaped or were released when the aquaculture operations did not become profitable and are now serious pests. Therefore, despite the negative experience in the Hawaiian Islands particularly, people from other islands may yet be tempted to introduce this species. *Pomacea canaliculata* should be considered a potentially serious threat and every effort should be made to prevent its further spread into the Pacific region.

History of *P. canlaiculata* introductions

Hawaiian islands.

Kauaʻi - 1991; Oʻahu - 1990; Maui - 1989; Länaʻi - 1995; Hawaiʻi - 1992 (Cowie 1995a, 1996c, 1997).

Papua New Guinea. 1990 (Laup 1991; Anon. 1993; incorrectly identified as *Pomacea lineata*).

Guam. 1989 (Eldredge 1994b; Smith 1992a).

Other introduced ampullariids recorded in the Pacific are:

Pomacea bridgesii. Hawaiian islands (Kauaʻi, Oʻahu, Hawaiʻi) -- Cowie 1995a, 1997, in press a.

Pomacea paludosa. Hawaiian islands (Maui) -- Cowie 1995a, 1997, in press a.

Pila conica. Hawaiian Islands (Oʻahu, Molokaʻi, Maui) -- Cowie 1995a, 1997, in press a; Belau (Palau) (eradicated) -- Eldredge 1994b; Guam -- Smith 1992.

None of these species seems to pose as serious a threat as does *Pomacea canaliculata*. However, all four are difficult to distinguish from each other, even by experts, and there are a number of other potentially voracious ampullariid species so far not recorded in the Pacific (e.g., *Marisa cornuarietis*). Therefore the best approach would be to guard against the introduction of all species of Ampullariidae.

[1] These case studies originally appeared in the following: Cowie, R. H. 2000. Non-indigenous land and freshwater mollusks in the islands of the Pacific: conservation impacts and threats. Invasive species in the Pacific: a technical review and draft regional strategy. South Pacific Regional Environment Programme. For complete citations please refer to this document at www.sprep.org.ws.

Salvinia Molesta in Sri Lanka

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Salvinia (*Salvinia molesta*) is one of four species that are members of the *S. auriculata* complex (Forno, 1983). Other members include *S. auriculata, S. biloba*, and *S. herzogii*. On the upper surface of mature leaves, members of this complex all have hairs on the tip of each papilla that are joined to form a bird cage-like structure. Other species in the genus have hairs on the tip of each papilla, and each hair divides at the end into three or four free arms not joined into a cage. Within the *S. auriculata* complex, all species are very similar in their vegetative morphology. Therefore, reproductive structures should be used for identifying species within the complex whenever possible. Other common names for *S. molesta* are giant salvinia, kariba weed, velvet weed, or water fern. Salvinia propagates vegetatively by division and is capable of colonizing large areas of stagnant fresh water in very short periods. Under ideal conditions, the plant grows at a doubling rate as brief as 2 days.

The native range of this species is southeastern Brazil. However, it is distributed throughout the tropics and subtropics. It has been described as one of the world's worst aquatic weeds and its spread has posed major problems in a number of tropical and subtropical countries, including Australia, Botswana, Kenya, Papua New Guinea, India, Indonesia, Malaysia, the Philippines, and Sri Lanka.

Sri Lanka is an agricultural country with estimated population of 18.73 million people (census in July 2001). Farmers and farming communities rely on a multitude of reservoirs for water because the country is prone to prolonged dry periods. Salvinia, observed in Sri Lanka since the early 1940's, has spread to a number of these reservoirs and the associated distribution and drainage systems. Water buffalo (*Bubalus bubalis*) may have been an important vector. Salvinia has caused a serious problem to the production of rice, which forms part of the staple diet. Rice production is affected because salvinia enters the rice fields and because it interferes with irrigation. In 1986, approximately 25% of Sri Lanka's 50,000 reservoirs (often referred to as tanks) were invested by salvinia.

The economic losses caused by salvinia in Sri Lanka were reported in 1989 by Doeleman as a result of study on "Assessment of costs and benefits of salvinia's biological control program in Sri Lanka." The program was sponsored by the Australian Centre for International Agricultural Research (ACIAR) and implemented by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in collaboration with the National Resources and Science Authority of Sri Lanka (NARESA).

Agricultural and other output, public health, and aquatic ecosystems in Sri Lanka have been adversely affected by salvinia. The economic losses caused by salvinia are categorized in terms of: (1) losses in rice production, (2) fishing losses, (3) other commercial losses, (4) human health costs, (5) environmental costs, and (6) abatement expenditure.

(1) Fishing losses

Salvinia's dense growth reduces light and oxygen, creating anaerobic conditions characterised by high concentrations of carbon dioxide and hydrogen sulphide that inhibit aquatic life. Salvinia contributes to fishing losses in affected reservoirs in two ways: 1) placing constraints on fish breeding sites which reduces population sizes and 2) reducing the effectiveness of gill netting. Fortunately, salvinia has not caused the relocation of fishermen and their families in Sri Lanka as it has in the Sepik River, Papua New Guinea in the early 1980s, where half of the 500 km^2 of lakes in the lower floodplains have been covered by impenetrable mats of salvinia.

In Sri Lanka, fishing accounted for 1.9% of 1987 GNP (113 billion Rp) and 19% of the fish supply was comprised of inland catch. River fisheries in Sri Lanka were not affected by salvinia but a quarter of reservoirs were affected in various degrees. It has been estimated that about 5% of the inland catch may have suffered losses due to salvinia and that on average the catch may be reduced from 20 to 40%. Accordingly, a low estimate of fishing losses would be 0.019 x 0.19 x 0.05 x 0.2 x 113,000 million Rp = 4.1 million Rp. The high estimate yields a figure of 8.2 million Rp.

(2) Losses in rice production

Amongst agricultural crops, only rice production appears to have suffered from salvinia. Salvinia is commonly introduced by irrigation water into irrigated rice fields. Rain fed rice cultivation may also be affected by salvinia, but only during wet periods.

The value of rice production in 1987 was estimated as 5.7% of GNP (113 billion rupees) or 6400 million rupees (Rp). The average area under rice cultivation in this year was estimated as about 418,000 Ha and the range of areas under salvinia infestation are 30,000 to 50,000 Ha. Crop losses in salvinia-invested areas were approximately 2-3%. On this basis, the low estimate of rice production loss was 30,000/418,000 x 0.02 x 6400 million Rp = 9.19 million Rp. The corresponding high estimate was 50,000/418,000 x 0.03 x 6400 million Rp = 22.97 million Rp.

(3) Other losses

Salvinia does impinge on activities other than rice production and fishing. These activities include power generation, water transport, washing and bathing. Due to the challenges in determining costs for these activities, only coarse-scale estimates are possible: 200,000 Rp for a low estimate and 500,000 Rp for a high estimate for 1987.

(4) Human health costs

Sri Lanka, as with many other tropical countries, is suffering from a resurgence of vectored diseases, e.g., malaria, filariasis, dengue fever, and encephalitis. Chemical controls, widely and successfully used in the 1950s, have resulted in resistant strains of mosquitoes. Salvinia increases breeding opportunities for the mosquitoes because the formation of vegetative mats reduces wave action and creates the shallow conditions the mosquitoes prefer for breeding.

The full extent of salvinia's contribution to mosquito-borne diseases is not known. However, salvinia plays a major role in filariasis. Filariasis is transmitted by the *Mansonia* genus of mosquitoes which favors salvinia. Unfortunately, there are no field studies to provide guidance on the costs of salvinia for filariasis and other human diseases. Assuming that salvinia, by providing a breeding ground for the mosquitoes, will add between 1 and 2% to the incidence of vector disease, the cost of the increase in disease incidence is crudely measured as the % increase in the health budget spent on this type of disease (around 30% of the total budget of 1,935 million Rp in 1987). In 1987, a low estimate of the health costs of salvinia was 0.01 x 0.30 x 1,935 million Rp = 5.8 million Rp. The high estimate doubles these costs to 11.6 million Rp.

(5) Environmental costs

No estimates have been made for environmental costs. Unlike the salvinia problems that developed in the Sepik Delta in Papua New Guinea, there has been no relevant research and thus there are no records of salvinia threatening natural communities in Sri Lanka. However, it is clear that salvinia can rapidly reduce a complex ecology to monoculture. Thus, as salvinia has spread in Sri Lanka, aquatic plants and animals must have suffered as a result.

(6) Abatement expenditure

In addition to the economic costs associated with loss of rice production due to salvinia infestations, management costs are incurred (termed “abatement costs”).

Abatement measures for salvinia in Sri Lanka are mostly done by mechanical control, for example, physical removal, using booms and occasionally a major clean-up exercise organized by relevant authorities. The Department of Agriculture estimated that 2-3 hours of labour on average per month per hectare is needed for the affected farmers to keep irrigation and drainage channels free from salvinia and pumps protected. Based on the estimate that 30,000 to 50,000 Ha of rice fields might be affected by salvinia and using 1987 agricultural wage per hour of 7.5 Rp, a low abatement cost can be calculated, at 30,000 x 2 x 12 x 7.5 Rp = 5.4 million Rp. The high abatement cost estimate is 50,000 x 3 x 12 x 7.5 Rp = 13.5 million Rp.

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ANNEX II: LIST OF PARTICIPANTS

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ANNEX III: AGENDA

Day 1: 18 October 2002

Time	**Topic**	**Speakers**
8:30 AM	Welcome and introductions	Richard Mack
8:50 AM	Project overview	Jamie K. Reaser
9:00 AM	Regional perspectives addressing the following questions (20 min each, plus 5 min Q & A): • What are believed to be the major biological and socio-economic impacts of IAS on island ecosystems? • What variables (e.g., island history, ecotypes, island size and distance, pathways, climate, region of the world, etc) are believed to influence the impacts of IAS on island ecosystems? • What are the "best practice" measures for the prevention, eradication, and control of IAS in island ecosystems? How do the principles/practices differ from continental systems?	• Quentin Cronk • Lu Eldredge • John Mauremootoo • Dennis O'Dowd
10:30 AM	Break	
11:20 AM	Regional perspectives continued.	• Sigurdur Thraisson • Moses Kairo • Leliua Vaiutu
12:30 PM	Lunch	
01:30 PM	• What are believed to be the major biological and socio-economic impacts of IAS on island ecosystems? • What variables (e.g., island history, ecotypes, island size and distance, pathways, climate, region of the world, etc) are believed to influence the impacts of IAS on island ecosystems? • What are the "best practice" measures for the prevention, eradication, and control of IAS in island ecosystems? How do the principles/practices differ from continental systems?	Facilitated
03:30 PM	Break	
03:50 PM	Group discussion of questions 1-3 continued.	Facilitated
05:00 PM	Close	
06:30 PM	Dinner	Home of Lu Eldredge

Day 2: 19 October 2002

Time	Topic	Speaker(s)
09:00 AM	**Group discussion of the following questions:** 1. What case studies (data) exist to document the impacts of IAS on island ecosystems and through whom can this information be obtained? 2. What gaps in knowledge exist and how might these gaps be filled? [gaps in knowledge, opportunities for filling gaps] 3. What can be accomplished in an assessment of the impact of IAS on island ecosystems in 9-months? [goals] 4. What are the steps to undertaking a 9-month assessment (including timeline)? [timeline] 5. Who needs to be involved in the assessment and how? [contributors – roles and responsibilities] 6. What are the first steps and who will take them [priorities and catalytic actions]?	Facilitated
10:30 AM	Break	
10:50 AM	Group discussion of questions 4-6 continued, including assignment of "next step" tasks.	Facilitated
12:00 PM	Lunch	
01:00 PM	Subgroups undertake "next step" tasks.	
02:30 PM	Reconvene, subgroup status reports.	
04:00 PM	Closing and Beach	

ANNEX IV: LIST OF DOCUMENTS

The following documents and citations were exchanged among meeting participants.

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ANNEX V: SUMMARY OF MAIN POINTS AND ISSUES

The following points were assembled from notes taken during expert presentations and discussions. They form the basis of the general conclusions and recommendations brought forth from the workshop, which are contained at the beginning of this document.

CONCLUSIONS

Biology
IAS are plants, animals and other organisms that have been moved into areas where they don't naturally occur, causing major environmental impacts. IAS are among the top drivers of environmental change globally.
Islands are especially vulnerable to biological invasions and numerous species extinctions have resulted, every island is highly likely to experience a biological invasion eventually.
The impacts of IAS on island ecosystems extend beyond natural ecosystems and losses of biodiversity to human health and agriculture, particularly from introduced pathogens and parasites.
IAS directly impact biodiversity on island ecosystems, through competition, predation, alteration of species abundances, habitat modification, novel mutualisms, loss of genetic diversity, and through hybridization of invasive species with natives.
IAS alter temporal processes on island ecosystems such as successional dynamics, and can change the frequency and intensity of disturbances such as floods and fire.
Although ballast water is widely recognized as a means by which IAS are moved around the world, the fouling of ships and other mobile structures by marine organisms is also a significant pathway for invasion.
In marine systems, artificial substrates are associated with the sudden appearance of IAS.
In marine systems, the number of IAS declines sharply upon leaving the harbor.
In terrestrial systems, dramatic changes in ecosystem function and disturbance cycles can occur following an invasion, such as nutrient cycling and fire regimes.
IAS can decrease ecosystem resilience following a natural disturbance and as a result intensify disturbance impacts, such as soil erosion.
In simple island ecosystems, IAS can unleash complex, unexpected outcomes, such as the formation of new associations or assemblages that amplify existing problems. Impacts from IAS can be very rapid, acute, chronic, cryptic, long-term, and cascading, and magnifying. The presence of other IAS influences the impacts of an invasive species on an island ecosystem.
Disturbance (natural and anthropogenic) facilitates the establishment and spread of IAS.
Several factors influence the impacts of IAS on island ecosystems including ecosystem heterogeneity, island shape and topography, and species plasticity, flexibility and species susceptibility to mutations.
Socioeconomic
Agriculture, tourism, water supply, biodiversity, and even human health have been negatively affected by IAS. IAS cause decreased food

security, water security and impact human health in terms of diseases, loss of native medicinal plants, nutrition, and increases in pesticide use to control IAS.
IAS can place considerable constraints on sustainable development and economic growth. IAS can cause the loss of income for commercial activities, e.g., forestry and agriculture, and the livelihood of individuals. Economic costs accrue due to IAS prevention, eradication, and control. Additional economic impacts of IAS include the loss of opportunity to utilize natural resources either directly (e.g., pharmaceuticals) or indirectly (e.g., tourism), unrealized exports or commercialization, and trade embargoes resulting from contamination.
Invasion pathways on islands are usually linked with human activities. Patterns of human settlement often determine where IAS will be found and influence the impact of IAS on island ecosystems.
Historical linkages between countries (e.g., colonies vs. protectorates, degree of international contact), as well as the culture of the colonizing country, play a strong role in determining the degree of invasion occurring in the colony or former colony as well as the kinds of species that were introduced.
Policy or sectoral conflicts may arise when an IAS have socio-economic benefits but also have adverse biological impacts. Strong lobbies may exist to introduce species that are harmful or that have not yet been assessed for invasiveness.
Most ships docking at small islands arrive full of cargo and leave empty, taking on water for ballast while discharging cargo. This makes most Small Island Developing nations exporters of ballast water, not recipients.
Islands without indigenous peoples may currently be inhabited by people who lack knowledge of and an affinity for the native flora and fauna, and who therefore harbor a mentality of exploitation rather than conservation. This affects attitudes towards conservation and restoration.
Trade volume is a significant contributor to the current status biological invasions on islands.
On some Caribbean islands, IAS are viewed primarily as an agricultural problem.
The failure of a sitting government to address serious IAS impacts has lead to a loss of power in at least one small island nation.
The proximity and shared culture of nearby islands can lead to the rapid movement of people and goods, and informal trade between islands. Existing quarantine systems may be inadequate and legislation related to importation may be out of date and therefore fail to prevent IAS introductions.
Cooperation between countries may be poor. For example, one country infected with a pest may refuse to take measures to prevent its spread to other countries.
IAS can cause the loss of aesthetic value and also lead to the alteration or loss of cultural heritage.
IAS can cause the loss of biological heritage and the loss of scientific opportunities.
IAS also increase fears about agricultural and biological terrorism.
Existing legal frameworks and diverse economies also influence the impacts of IAS on island ecosystems, particularly where there are gaps or inconsistencies in legal and policy frameworks can exacerbate the impacts of IAS.
Lack of access to existing technologies and information to address IAS incursions results in impacts that might have otherwise been avoided or mitigated. Access to foreign assistance can aid island nations in prevention and management efforts, but it can also serve as the source of introductions (“Aid Trade’).

Animal rights lobbies opposed to destroying any animals may limit management responses to incursions and existing invasions.
Analysis/Prediction
Prevention is the best way to safeguard islands from the impacts of IAS.
Early detection of newly arrived organisms is necessary to keep invaders from establishing and spreading.
IAS are a problem on all islands, but the problem is not without remedy and there are increasing numbers of successful and extremely cost-effective management methods to reverse the damage and prevent new problems from occurring. Given the application of best practices, IAS on islands are potentially manageable in terms of prevention and eradication for certain species. Impacts from invasions are potentially manageable and potentially reversible.
Pathway management is more tractable on island systems relative to continents because there are fewer entry points.
Important questions/ facts unknown
What quantitative data on the impacts of IAS exists for island ecosystems?
Is resilience on island ecosystems lower than that of mainland ecosystems?
Are rates of invasion on islands increasing globally?
Are the number of donor regions and frequency of introductions increasing for islands?
Are other environmental factors, such as climate change, exaggerating the impacts of IAS?
Are there impacts from IAS that have not yet been realized due to a lag phase?
When novel species associations form due to biological invasions, what will happen in terms of species-species/species-environment interactions?
Are there similarities between the impacts of IAS on geographically isolated island ecosystems and ecologically isolated communities on mainland systems?
More information is needed about extinctions on continental systems in order to determine whether or not the rates of extinction due to IAS are higher on islands than continents. Lack of ecological and taxonomic information prevents prediction of impacts and even identification of species as introduced or native.
What are the invasion pathways on island ecosystems and what are the significance of their impacts?
What is the threshold between a non-native species and an IAS?
What are the long-term consequences of biological invasions on island ecosystems particularly in terms of their cascading impacts and the reversibility of those impacts?
What are the socio-economic impacts of IAS on island ecosystems? What is the reversibility of the socio-economic impacts of IAS?
What is the efficacy of current biosecurity measures in reducing impacts?
What is the public perception of IAS and their impacts on island ecosystems?
What are the rates of introduction for particular taxonomic groups?
What factors are critical to the establishment IAS?
What is the rate at which IAS fail to establish?

A lack of knowledge about the ecology of both the systems invaded and the IAS themselves.

RECOMMENDATIONS

Information- gathering
Support and undertake studies of fouling as an invasion pathway, as well as the biological and socio-economic impacts of fouling organisms on marine ecosystems.
Conduct fundamental research on the basis of insect-plant specificity at the biochemical and ecological level.
Conduct island bioinventories. Despite islands having small and tractable biotas, the bioinventory is far from complete on many, especially when it comes to invertebrates. On islands, more than on any other system, complete bioinventory is achievable.
Conduct research on how to incorporate stochastic processes that may be important in the early stages of invasion into population models.
Document where within the range of a species do invasive island populations come from.
Develop more complete knowledge and identification of non-pathogenic microorganism invasions.
Better methods are needed to identify and quantify ecosystem services.
Apply social science research methods to identify community values and ways of involving communities.
Implement more ecological experiments, in the form of perturbations, field trials or "adaptive management". These need to be undertaken to improve sustainable management regimes.
Improve knowledge of species interactions, food webs and competitive relations are needed for specific island system in relation to proposed management actions.
Conduct retrospective and continuing studies of biocontrol. Too often valuable data is lost because monitoring of biocontrol is discontinued after remediation is achieved.
Improve knowledge of invasion risk and patterns of spread to prioritize species and reduce uncertainty, through higher quality data and modeling. In particular: identify what the minimum thresholds for the initial population size of an introduction for a successful invasion (single gravid female, or more).
Capacity-building
Raise awareness of the problem of fouling by IAS with governments, relevant industries, tourists and recreationists, and local communities (especially those associated with coral reefs).
Deposit voucher specimens in appropriate museums to assist with species identification.
Engage the marine sector on IAS issues. This is a priority for island nations.
Develop partnerships among those with financial, technical, and informational resources and those in need; in particular, neighbors, sources of IAS, trading partners.
Engage trade related bodies in IAS issues on islands.
Build strong relationships between territories and states.
Policy development/implementation

Develop and enact best management practices and policies to physically clean ships hulls and marine equipment so as to minimize the risk of transport of fouling organisms. Develop environmentally sound alternatives to the toxic anti-fouling agents that are gradually being removed from use.
Establish surveillance programs to detect and penalize “polluters” who introduce IAS via fouling.
Establish early detection and rapid response programs with an aim to eradicate IAS before they can become established and spread.
Address and resolve the lack of continuity in staff and expertise available to managers addressing IAS on islands. Address logistical issues with regard to access to technology and materials.
Target efforts at specific audiences (i.e., tourists).
Take precautionary measures for inter-island movements and movements of organisms between mainland.
Implement biosecurity measures at sub-national and individual island levels.
Develop national and regional contingency plans.
Integrate marine and terrestrial systems need into management.
Establish procedures for collaboration between (probable) source and receiving nations.
Create open access to relevant information (survey) and ensure that data is repatriated.
Emphasize the importance of scientific advisory panels.
Institute legal frameworks.

ANNEX VI: Press Release
Prepared at the Islands Assessment Workshop October 19, 2002

ANNEX VII: Fouling of Marine Ecosystems by Invasive Alien Species: A Call to Action

Background

Invasive alien species (IAS) are organisms that have been moved (purposely or inadvertently) from their native ecosystem into a new location where they cause harm to the economy, biological systems, or human health. They are among the top drivers of environmental change globally and can place considerable constraints on sustainable development and economic growth.

IAS are little studied, yet they pose a significant threat to marine ecosystems and those who depend upon them.

Examples of impacts include the following:

- Declines in commercial and recreational fisheries
  - The comb jelly *Mnemiopsis leidyi* contributed to the complete collapse of kilka (anchovy) fisheries in the Black Sea.
  - The Northern Pacific Sea star *Asterias amurensis* is having a drastic economic effect on the shellfish industry in Tasmania.
- Losses of aesthetic values and tourist income
  - The seaweed *Gracilaria salicornia* washes ashore, polluting Waikiki Beach in Hawai'i and a single alga species, *Kappaphycus*, has replaced spectacular coral reef communities in Kaneohe Bay.
  - Snowflake octocoral *Carijoa riisei* from the Caribbean now forms single species masses among black coral in Hawai'i hindering recruitment.
- Threats to human health
  - Dinoflagellates have been introduced in ballast water and have caused toxic "red tides" that poison fish and people who eat them.
- Animal health
  - Introduced parasites and diseases that have caused mortality in native marine mammal populations.

On 18-19 October 2002, the Global Invasive Species Programme (GISP) brought together an international team of experts (see Annex) in Honolulu, Hawai'i, to design an assessment of the biological and socio-economic impacts of invasive alien species on island ecosystems, including their marine environments.[3]

In the course of their deliberations, the experts concluded that:

While ballast water is now widely recognized as a means by which IAS are moved around the world, the fouling of marine organisms on ships and other mobile structures is also a significant pathway for invasion

[3] The assessment was called for by the Convention of Biological Diversity (CBD) at the sixth Conference of the Parties (www.biodiv.org). It was funded by the CBD and the U.S. Agency for International Development.

and must be considered as high a priority by policy makers, natural resource managers, relevant industries, and investigators.

Fouling the Oceans

More than 45,000 registered cargo ships (Llyod's Register, 2000) and hundreds of thousands of recreational craft travel the world's seas. Hundreds of species are transported either by ballast water contained in these vessels or as "hitchhikers" attached to the ships (i.e., fouling organisms). Nearly any form of movable marine equipment can serve as a means of transport for fouling organisms; from barges and drilling platforms, to fishing and diving gear, to tools for scientific research and marine debris.

Most ships docking at small islands arrive full of cargo and leave empty, taking on water for ballast while discharging cargo. This makes most Small Island Developing States (SIDS) exporters of ballast water, not recipients. Therefore, hull fouling is their most important pathway for the introduction of marine IAS.

The Call

The participants of the expert consultation call upon governments, inter-governmental and non-governmental organizations, industries, and other relevant bodies to:

- Raise awareness of the problem of fouling by IAS with governments, relevant industries, tourists and recreationists, and local communities (especially those closely associated with coral reefs).
- Develop and enact best management practices and policies to physically clean ships hulls and marine equipment so as to minimize the risk of transport of fouling organisms.
- Develop environmentally sound alternatives to the toxic anti-fouling agents that are gradually being removed from use.
- Establish surveillance programs to detect and penalties for "polluters" who introduce IAS via fouling.
- Establish early detection and rapid response programs with an aim to eradicate IAS before they can become established and spread.
- Support and undertake studies of fouling as an invasion pathway, as well as the biological and socio-economic impacts of fouling organisms on marine ecosystems.

For further information on fouling, contact Dr. Lucius G. Eldredge, Bishop Museum, Honolulu, Hawai'i at psa@bishopmuseum.org.

ANNEX VIII: Research Needs: Invasive Alien Species on Islands

Basic research

(1) Fundamental research on the basis of insect-plant specificity at the biochemical and ecological level. *Rationale:* Biological control is highly valuable in the control of established plant invasions on islands, where resources are often not available for physical control, but insect agents have to be highly specific to avoid damaging endemic native flora. However little is known about the biology of specificity.

(2) Bioinventory. Despite islands having small and tractable biotas, the bioinventory is far from complete on many, especially when it comes to invertebrates. On islands, more than on any other system, complete bioinventory is achievable. *Rationale:* for detailed understanding of invasive impacts, complete bioinventory is desirable. Also, bioinventory in source regions (for little known invertebrate groups in particular) will aid understanding of pathways of invasion.

(3) Research on how to incorporate stochastic processes that may be important in the early stages of invasion into population models. *Rationale:* Better population modelling may lead to resolution of the problem that at present we cannot predict which introductions will become successful invaders. Most introductions do not become invasive.

(4) Where within the range of a species do invasive island populations come from? *Rationale:* An understanding of the genesis of IAS from within the population variation of a species, will lead to increased understanding and prediction of IAS, and the identification of high risk provenances which should be kept out of islands at risk, even if they have non-invasive provenances.

(5) Invasion of non-pathogenic microorganisms in ecosystems are little understood or known because of the difficulty of studying them. *Rationale:* In sensitive macrobiota-poor ecosystems such as sub-Antarctic islands, environmental microorganisms may constitute a very important ecosystem-altering invasion threat. Baseline studies of microorganisms on islands are needed, as well as studies of invasion by microorganisms.

Management/Agbio Research needs

(6) The science of identifying and quantifying ecosystem services is in its infancy, and better methods are needed. *Rationale:* Protection of ecosystem services is particularly important on islands which have limited resources. Quantification of ecosystem services is important for prioritisation, understanding of impacts.

(7) Methods of social science research need to be applied to identifying community value and ways of involving communities. *Rationale:* Communities are often small on islands easing community communication but also making conflict avoidance especially important.

(8) More ecological experiments, in the form of perturbations, field trials or “adaptive management”, need to be undertaken to improve sustainable management regimes. *Rationale:* Lack of experimental data is a significant cause of conservation failure in managing IAS on islands. Experiments are particularly difficult to do on islands as they are often difficult to access by researchers and consequently experimental data is often lacking.

(9) Improved knowledge of species interactions, food webs and competitive relations are needed for specific island system in relation to proposed management actions. *Rationale:* Improved knowledge of interactions will lead to better prediction of biocontrol outcomes, and

prevention of ‘cascading’ effects within ecosystems (invasive meltdown). On islands in particular a “holistic” approach involving all elements of these discrete systems is possible and desirable.

(10) Retrospective and continuing studies of biocontrol are needed. Too often valuable data is lost because monitoring of biocontrol is discontinued after remediation is achieved. *Rationale:* Negative impacts and long term effects and cycles, which could be used to improve biocontrol success rates, are often lost. Islands in particular present discrete systems for long-term and retrospective monitoring.

(11) Better knowledge of invasion risk and patterns of spread are needed to prioritize species for management and reduce uncertainty through higher quality data and modelling. In particular: what are the minimum thresholds for the initial population size of an introduction for a successful invasion (single gravid female, or more?). *Rationale:* Uncertainty poses considerable difficulty for policy-makers, and greater quantification will lead to more decision prevention policy.

<u>ANNEX IX:</u> **Draft Outline** (15 page Information Document)

Executive Summary/Abstract

A. **Preface**

1. Purpose of assessment
   - a) Driven by CBD: called for by Parties because it was recognized as being so urgent.
   - b) Why islands? (Elton's book, Vitousek's model)
     - i. Islands represent a level of transformation in the last 500 years
     - ii. Extraordinary opportunity – constrained size, bounded by water, model system for other ecological systems
     - iii. Pathway analysis
     - iv. Success stories as exemplars
     - v. Islands are at the forefront of global change. IAS may exaggerate any other global change impacts
   - c) Definition of impacts
2. Use of this document
   - a) Intended for policy-makers (CBD report)

B. Introduction

1) Invasive alien species defined
2) Islands defined
3) Causes of biological invasion (1/2 page, well cited)
   - a) Pathways
   - b) Intentional/unintentional
   - c) Facilitation
4) History, status, and trends of island invasions
   - a) History and trends
     - i) Asian/Polynesian migration
     - ii) What happens once an island becomes a colony?
       - Compare fate of islands under different colonizers
       - Colonization of Mauritius and Madagascar (Ask John Mauremootoo)
       - Perception by Europeans that island plants of little value
       - How does that vary (species, pathways) by who is colonizing (see Green Imperialism, Seeds of Change)?
     - iii) Current Status – the vast number of islands have been subjected to radical change, however there are a few small islands (e.g., Henderson, Christmas Island) that are in reasonably good shape.

C. Biological Impacts***

1. Overview: Impacts defined and how they can be assessed
   - a) Genetic diversity
     - i. Case studies
   - b) Species
     - i. Case studies
   - c) Habitats/communities
     - i. Case studies
   - d) Ecosystems
     - i. Case studies

*Ecosystem type: marine, FW aquatic, coastal, terrestrial

**Geographic location: Indian Ocean, temperate
***Taxa: plants, vertebrates, invertebrates, microbes

2. Summary of available data
    a) Established points
    b) Uncertainties
    c) Future needs
    d) Opportunities (e.g., existing mechanisms that could be applied)

D-1. Socio-Economic Impacts

1. Overview
    a) Fisheries
    b) Agriculture
    c) Tourism
    d) Human health
    e) Conflict
    f) Human migration
    g) Cultural heritage
2. Summary of available data
    a) Established points
    b) Uncertainties
    c) Future needs
    d) Opportunities

*Ecosystem type: marine, FW aquatic, coastal, terrestrial
**Geographic location: Indian Ocean, temperate
***Taxa: plants, vertebrates, invertebrates, microbes

D-2: Integration of biological and socio-economic impacts

a) Setup statement to mitigation

E. **Mitigation of Impacts**

1. Overview of options
    a) Principles
        i. Prevention
        ii. Early detection and rapid response
        iii. Eradication
        iv. Control
        v. Restoration
    b) Practices unique to islands
        i. Prevention
        ii. Early detection and rapid response
        iii. Eradication
        iv. Control
2. Summary of available data
    a) Established points
    b) Uncertainties
    c) Future needs
    d) Opportunities

F. Conclusions and Recommendations