UNEP

CBD

CONVENTION ON BIOLOGICAL DIVERSITY

Distr.
GENERAL

UNEP/CBD/SBSTTA/9/INF/33
5 November 2003

ENGLISH ONLY

SUBSIDIARY BODY ON SCIENTIFIC, TECHNICAL AND TECHNOLOGICAL ADVICE
Ninth meeting
Montreal, 10-14 November 2003
Item 7.1 of the provisional agenda*

PILOT ASSESSMENTS: THE ECOLOGICAL AND SOCIO-ECONOMIC IMPACT OF INVASIVE ALIEN SPECIES ON ISLAND ECOSYSTEMS

Note by the Executive Secretary

EXECUTIVE SUMMARY

The present note, prepared in response to recommendation VI/5 of the Subsidiary Body on Scientific, Technical and Technological Advice, explores the vulnerability of islands to biotic invasion. It reports on known ecological and socio-economic impacts of invasive alien species (IAS) on islands, and provides guidance and information that can help minimize the impact of invasive alien species on island ecosystems.

While islands may not be more susceptible to invasions by alien species than continental landmasses they are, however, considered to be particularly vulnerable to the impacts of such invasions. The risk of the introduction, establishment, and spread of invasive alien species in island systems depends on a number of ecological and socio-economic factors that are context specific and often inter-related. The major pathways of introduction of invasive alien species to island ecosystems are diverse, and are strongly influenced by an island State's or territory's trade status. The resilience of island ecosystems is determined by their ability to resist or cope with alien species.

In practice, few rigorous frameworks for quantitative risk analysis, nor adequate data, currently exist to enable scientists to reliably predict the invasive potential of organisms or the resilience of ecosystems.

Invasive alien species are believed to be the most significant driver of the decline of plant and animal populations and species extinctions in island ecosystems. Their impacts on human health or the economy can be considerable. When evidence of impacts can be obtained and communicated reliably and rapidly, a wide range of constituencies can often be motivated to support an effective response.

* UNEP/CBD/SBSTTA/9/1.

There are many examples of successful eradication and control programmes of invasive alien species on islands, and greater awareness of the problem is increasing the capacity of countries to prevent their movement and introduction. Furthermore, the relatively small size and contained nature of island ecosystems can present opportunities for the management of invasive alien species that can be more effective than in mainland ecosystems.

The strategies required to minimize the impacts of invasive alien species are well known. The present note lists available sources of guidance for developing and implementing effective, strategic programmes for the prevention, eradication, and/or control of invasive alien species. It includes suggestions for overcoming socio-political, financial, scientific, technical, and technological challenges to the implementation of prevention and management programmes.

Although the prevention, eradication, and control of invasive alien species on islands (and in other ecosystems) present scientific, political, and ethical challenges, the problem can be significantly reduced through concerted action. Scientifically based information and effective tools need to be provided to policy makers and resource managers so that well-informed decisions can be taken. Co-operative programmes among governments and relevant institutions and organizations can facilitate the implementation of strategic, holistic, and timely measures to manage invasive alien species.

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I. BACKGROUND

1. The sixth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA), in its recommendation VI/5), decided to initiate, in accordance with decision V/20 (para. 29 (b)) of the Conference of the Parties, a number of pilot assessments on current priority issues, including *inter alia* on the impacts of invasive alien species (para. 6(d) of recommendation VI/5).

2. In paragraph 24 of decision VI/23 [1] the Conference of the Parties urged Parties, Governments and relevant organizations to promote and carry out assessments on *inter alia* the impact of alien species on biological diversity (para. 24(b)) and the socio-economic implications of invasive alien species particularly the implications for indigenous and local communities (para. 24(d)). In the same decision, the Conference of the Parties recognized that invasive alien species represent one of the primary threats to biodiversity, especially in geographically and evolutionary isolated ecosystems, such as small island developing States (preamble to Section II on the Guiding Principles).

3. In response to the provisions of this decision, the Executive Secretary commissioned the Global Invasive Species Programme (GISP) to work with Parties and other bodies to assemble case-studies on the ecological, social and economic impact of invasive alien species with particular attention to small islands.

4. The assessment report summarized in this document is based on literature review, submitted case-studies and an experts consultation hosted by GISP from 18 to 19 October 2002 in Honolulu, Hawai'i. It was subjected to peer-review and the reviewers' comments have been incorporated as appropriate. The full report is available on the Website of the Secretariat at http://www.biodiv.org/doc/ref/ais-gisp-report-en.doc. [2]

II. THE ECOLOGICAL AND SOCIO-ECONOMIC IMPACT OF INVASIVE ALIEN SPECIES ON ISLAND ECOSYSTEMS

A. Introduction

1. Island ecosystems

5. Unless otherwise specified, *islands* and *island ecosystems* include terrestrial, inland water, and coastal marine environments. Although this note addresses island ecosystems collectively, it places emphasis on oceanic islands and particularly Small Island Developing States (SIDS) because these systems are often perceived to be the most at risk. For evolutionary and socio-economic reasons, the processes and impacts of biological invasion differ among islands, as well as among types of environments on the same island. Case studies are provided to illustrate these differences.

6. The geographic isolation of oceanic islands has facilitated the establishment and evolution of biological communities comprised of distinct and limited arrays of species compared with continental systems. The presence of the marine environment and physical distance between the mainland and islands limit the number and taxa of organisms that can naturally reach and colonize islands. In many instances, groups such as large-seeded plants and large mammals are, therefore, totally absent from the biotic

[1] One representative entered a formal objection during the process leading to the adoption of this decision and underlined that he did not believe that the Conference of the Parties could legitimately adopt a motion or a text with a formal objection in place. A few representatives expressed reservations regarding the procedure leading to the adoption of this decision (see UNEP/CBD/COP/6/20, paras. 294-324). This footnote applies to all mentions of decision VI/23 throughout this document.

[2] Edited by Jamie K. Reaser (reaserj@si.edu) and Laura Meyerson (meyerson@heinzctr.org)

community that evolved on many islands (unbalanced fauna or disharmony; MacArthur 1972, Mueller-Dombois 1981, Loope and Mueller-Dombois 1989). For example, Hawai'i lacks native mammal species (with the exception of a bat), two-thirds of the world's insect orders (Loope and Mueller-Dombois 1989), and mangrove species (see case study by A. Demophoulos in Meyerson and Reaser 2003)**.** The long history of isolation coupled with the high topographic, and thus microclimatic, diversity typical of many islands (especially volcanic islands) led to the evolution of organisms (adaptive radiation) that are unique (endemic) to specific islands or island chains (Mueller-Dombois 1981). In Mauritius, for example, 70% of the species of flowering plants, 80% of the bird species, and 90% of the reptile species are endemic (see comments by J. Mauremootoo in Meyerson and Reaser 2003).

7. Compared with organisms found on the mainland, the space-constrained island species are generally less vagile (less capable of moving elsewhere)[3], comprised of fewer populations, and/or have smaller total population sizes. These characteristics, coupled with isolation and endemism, make island ecosystems especially sensitive to disturbance and island species vulnerable to extinction at rates that often exceed those of continental systems (Mueller-Dombois 1981, Loope and Mueller-Dombois 1989, D'Antonio and Dudley 1995). For example, 90% of Hawai'i's flora is endemic and approximately 25% has been listed as threatened or endangered (Harrington and Ewel 1997). For extensive reviews of the ecological characteristics of islands, see MacArthur and Wilson (1967), Carlquist (1965, 1974), and Williamson (1981). Loope and Mueller-Dombois (1989) provide a table that compares selected parameters for various island groups.

8. Due to the vulnerability of island ecosystems (see also section *II.*) and the people who depend upon them, the protection of island biodiversity has become a priority for the United Nations.[4] The Convention on Biological Diversity has repeatedly recognized the need to give particular attention to biodiversity conservation and sustainable development on islands and in other geographically and evolutionarily isolated ecosystems.[5]

2. Invasive alien species

9. The definitions for *invasive alien species* (IAS) and related terms are those adopted by the sixth meeting of the Conference of the Parties (VI/23). Invasive alien species are one of the most significant drivers of environmental change worldwide (Mooney and Hobbs 2000, Sala et al. 2000, McNeely et al. 2001). They contribute to social instability and economic hardship, consequently placing constraints on biodiversity conservation, sustainable development, and economic growth (McNeely 2001, McNeely et al. 2001). The globalization of trade, travel, and transport is greatly increasing the number of invasive alien species (both individuals and species) being moved around the world, as well as the rate at which they are moving (McNeely et al. 2001). At the same time, changes in climate and land use are rendering some habitats more susceptible to biological invasion (Mooney and Hobbs 2000). Even the most well protected natural areas are not immune to invasive alien species (Chapin v2000, Simberloff 2000a, Parkes et al. 2002, Tye et al. 2002, O'Dowd et al. 2003).

10. Article 8 (h) of the Convention calls on Parties to "as far as possible and as appropriate: Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species." At the sixth Conference of the Parties (COP 6), Parties adopted guiding principles and a programme of work for the implementation of Article 8 (h) (decision VI/23). This decision recognized invasive alien species as a primary threat to biodiversity in small island developing States (SIDS) and urged bilateral donors and other funding sources to make funding for development and implementation of IAS strategies and actions in geographically and evolutionarily isolated ecosystems an urgent priority.

[3] For example, many types of "flightless" birds have evolved on islands around the world

[4] http://www.unep.ch/islands.html#INTRODUCTION

[5] http:// www.biodiv.org

11. International and national responses to the invasive alien species problem have thus far, however, been insufficient to counter their increasing toll on biological diversity and society (McNeely et al. 2001, Reaser et al. 2003a). One of the most significant barriers to policy development and implementation has been the paucity of reliable quantitative information on the ecological and socio-economic impacts of invasive alien species. These data are needed to help decision makers understand the scale and complexity of the problem and to enable stakeholders to determine the costs versus the benefits of their actions (Perrings et al. 2000; McNeely et al. 2001; Pimentel 2002; Reaser et al. 2003a,b).

3. Islands and invasive alien species

12. *Impacts* are the effects or influences that invasive alien species have on various ecological or socio-economic components of island ecosystems and/or the human communities that depend upon island resources. As invasive alien species are harmful organisms by definition, their impacts, discussed in this note are “negative” (i.e., the costs of the organism to society are generally perceived to be greater than the benefits).

13. According to the Convention, an “environmental-impact assessment is a process of evaluating the likely environmental impacts of a proposed project or development, taking into account inter-related socio-economic, cultural and human-health impacts, both beneficial and adverse” (decision VI/7). Environmental impact assessments (EIAs) have become a common requirement for projects funded by governments and development assistance organizations. However, the practice of conducting and reporting on EIAs has often lacked the rigour and standardization necessary to support well-informed decision making at national and international levels. In order to address this problem, the World Bank has prepared the *Biodiversity and Environmental Assessment Toolkit* (Duke and Aycrigg 2000), and the sixth meeting of the Conference of the Parties to the Convention on Biological Diversity adopted, in decision VI/7 A, guidelines for incorporating biodiversity-related issues into environmental impact assessment legislation and/or process and in strategic environmental assessment.

14. Due to the complexity and relatively recent recognition of the invasive alien species issue, as well as the historic lack of adequate environmental impact assessments globally, there is a paucity of reliable, standardized information on the impacts of invasive alien species on islands, as well as other ecosystems. For the purposes of this note, therefore, it is important to note that the findings were not derived from environmental impact assessments, but have been compiled from a wide-range of studies conducted by scientists, natural resource managers, and economists. In some instances, the projects were designed to assess the impacts of invasive alien species on one or more aspects of biodiversity. In other cases, the studies were not conducted for these purposes, but nevertheless reported on the impacts of invasive alien species.

15. Although the majority of the information available on the impacts of invasive alien species on islands is based on anecdotal observations, the report is based on studies derived from research that has been published in peer-reviewed literature or through scientific and technical conferences, as well as the reports provided by the experts who participated in the associated experts consultation. While this decision limited the number of case-studies that could be made available to the Parties and other bodies through this assessment, it also serves to ensure that the information contained in the case-studies is reliable. Far more research has been conducted on the ecological impacts of invasive alien species than on the socio-economic consequences of biological invasion. The report necessarily reflects this situation and it is hoped that researchers, particularly those in the social sciences, will be inspired and supported to fill the existing information gaps.

16. This paper explores the vulnerability of islands to biotic invasion, reports on known ecological and socio-economic impacts of invasive alien species on islands, and provides guidance and information on resources that can help minimize the impact of invasive alien species on island ecosystems. While true islands are landmasses surrounded by water, other isolated biotas (e.g., those found on mountain tops or

in isolated lakes) often function as ecological islands. According to island biogeographic theory (MacArthur and Wilson 1967, Brown and Lomolino 1998), the results of this assessment might, therefore, be applicable to a wide range of geographically and evolutionarily isolated ecosystems.

B. Vulnerability

17. The Convention on Biological Diversity recognizes the importance of addressing threats to biodiversity across multiple levels of organization - ecosystems, habitats, species, and genes (Preamble[6], article 8[7] of the Convention) - because multiple interactions (e.g., energy flows, nutrient cycling) occur among these categories (ecosystem approach). Ecosystem goods and services (e.g., potable water, medicinal plants) are the tangible benefits to society derived from these interactions (Baskin 1997, Daily 1997).

18. Because of the intrinsic complexity and dynamism (changes over time and space) of most natural systems, scientists and policy makers find it useful to assess the vulnerability (risk of damage) of ecosystems and their components to specific natural and anthropogenic threats.[8] This enables them to make projections as to the future condition of ecosystem goods and services and attempt to make decisions that minimize the risks to these outputs (thus maximizing the benefits over the costs to society).

19. Islands have often been regarded as being more susceptible to invasion by alien species than mainland ecosystems (Darwin 1859; Carlquist 1965, 1974). However, with the exception of some taxa (Londsdale 1999), this appears to be a poorly supported generalization (D'Antonio and Dudley 1995). For example, there are an equal number of reports of the invasion of woody plants from continents and oceanic islands (Binggeli 1996). D'Antonio and Dudley (1995) correctly point out that susceptibility to biological invasion does necessarily coincide with vulnerability to the impacts of invasive alien species, and they argue that islands are in fact more susceptible to the effects of invaders.

20. In theory, the vulnerability of island ecosystems to impacts from invasive alien species needs to be considered from three perspectives:

(a) The risk of the i) introduction, ii) establishment, and iii) spread of invasive alien species;

(b) The intrinsic resilience of island ecosystems to invasive alien species; and

(c) The extrinsic resilience of island ecosystems to invasive alien species.

21. The *risk* of the introduction, establishment, and spread of invasive alien species in island systems (as well as other ecosystems) depends on a number of ecological and socio-economic factors (annex I) that are context specific and often inter-related. For example, the major pathways of introduction of invasive alien species to island ecosystems are diverse (annex II), and are strongly influenced by an island nation's or territory's trade status. Whether or not an invasion of an alien species is damaging depends of the how and to what degree the indigenous biotic community is disrupted (Mueller-Dombois 1981). The *intrinsic resilience* of island ecosystems is determined by the innate ecological factors that enable them to resist or cope[9] with alien species (e.g., existence of refugia, native predators, niche differentiation). An

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6 http://www.biodiv.org/convention/articles.asp?lg=0&a=cbd-00

7 http://www.biodiv.org/convention/articles.asp?lg=0&a=cbd-08

8 For examples, see "scenarios" work of the Intergovernmental Panel on Climate Change (IPCC; http//www.ipcc.ch/) and Millennium Ecosystem Assessment (MA; http://www.millenniumassessment.org/en/index.htm).

9 Note that in this paper, the term resilience is used broadly to address processes that are sometimes treated as separate concepts: resistance (ability of systems to resist biological invasion) and resilience (ability of systems to maintain its biological integrity once invaded).

island ecosystem's *extrinsic resilience* is dictated by external forces (e.g., natural disasters such as hurricanes; but more often socio-economic factors) that influence its integrity (ecosystem health).

22. The concept of ecosystem resilience has been rigorously debated among ecologists and has recently become the focus of numerous studies designed to evaluate the vulnerability of specific ecosystems to invasion by alien species. General discussions of the characteristics of invaded islands as they related to the ability of ecosystems to resist invasion and the impacts of IAS can be found in Mueller-Dombois (1981), Loope and Mueller-Dombois (1989), Simberloff (1995, 2000b), and Chapin et al. (2000). Studies of invasion resistance in specific ecosystems and taxonomic groups can be found in Simberloff (1986; insects in Hawai'i), Lake and O'Dowd (1991; giant African snail on Christmas Island), Duncan (1997; birds in New Zealand), Vidal et al. (1998; flora off South-East France), Stachowicz et al. (1999; marine systems), Sol (2000; birds in New Zealand), Gabriel et al. (2001; springtails on Marion Island near Antarctica), Holway et al. (2002; ants), Sara and Morand (2002; mammals on Mediterranean Islands), and Green et al. (in press; wood plants on Christmas Island).

23. The most important factors believed to influence the vulnerability of SIDS to environmental threats, including species introductions, have been reviewed previously (UNEP 1999 a, b, c, d), and are summarized in annex III with particular regard to invasive alien species. Lonsdale (1999) provides a model for evaluating invasive potential with regard to plants. Parker et al. (1999) offers the following formula for determining the overall impact of an invader:

24. The overall impact (I) of an invader on a specific geographic scale equals the total area occupied by the species (R) multiplied by the abundance of the invasive alien species (A) and further multiplied by a measure (E) of the impact per individual or per unit of biomass. Thus, $I = R \times A \times E$.

25. In practice, however, few rigorous frameworks for quantitative risk analysis, nor adequate data, currently exist to enable scientists to reliably predict the invasive potential of organisms and resilience of ecosystems (Leung et al. 2002). Predictive (and post hoc) analysis of impacts is further complicated because variables such as abundance and range are difficult to define and measure, variables (e.g., R, A, and E) are not independent, and the relationship among the variables can be non-linear (see discussion in National Research Council 2002). Nevertheless, numerous scientists are attempting to draw attention to and address these gaps and challenges (e.g., Kolar and Lodge 2002, National Research Council 2002, see also the Vulnerability Index Web[10]).

26. For further information on information gaps and research priorities relevant to invasive alien species vulnerability assessments and risk analyses frameworks in island ecosystems, see Meyerson and Reaser (2003).

C. Impacts

27. Historically, habitat destruction was appropriately regarded as the most significant factor impacting island biodiversity (Bramwell and Bramwell 1974). In New Zealand, for example, habitat destruction reduced forest cover from 68% to 14% over a 200 year period (Kuschel 1975). However, participants in the experts consultation associated with this assessment (Meyerson and Reaser 2003) believe that invasive alien species are now the most significant driver of population declines and species extinctions in island ecosystems, and organizers of a recent conference on the eradication of invasive alien species on islands state that, "There is no doubt that invasive (alien) species can cause severe economic and ecological damage (Mack et al. 2000). They may soon surpass habitat loss as the main

[10] SOPAC Environmental Vulnerability Index (EVI) Web and reference list. http://www.sopac.org.fj/Projects/Evi/evi_reference_list.htm

cause of ecological disintegration globally (Vitousek et al. 1997, Chapin et al. 2000) and are probably already the main cause of extinctions in island ecosystems" (Clout and Veitch 2002).

28. In theory, the ecological impacts of invasive alien species on islands (and other ecosystems) can:

(a) Occur at any level or across levels of biotic organization;

(b) Result from direct and/or indirect influences of the invasive alien species;

(c) Occur immediately or years after the introduction (i.e., only after prolonged lag time since arrival);

(d) Persist for the short- or long-term;

(e) Act synergistically to magnify or amplify other impacts on the system (including habitat destruction, see Sala et al. 2000);

(f) Be so subtle that they are not readily perceived, but be cumulative over time; and/or

(g) Interact and have cascading effects (i.e., effects that trigger additional effects throughout the system);

For further discussion of these issues and for specific examples, see the Meyerson and Reaser (2003).

29. By definition, Invasive alien species cause direct and/or indirect harm to one or more sectors of society. However, even through the impacts of invasive alien species on the environment, human health, or the economy can be significant, there is often a constituency (though typically small) that has a desire to protect (e.g., for animal welfare) or even propagate the species for various purposes (e.g., food for local consumption or export). This desire can lead to conflicts over the eradication and control of the invasive alien species (for examples, see McNeely 2001, Parkes et al. 2002, see S. Thrainsson comments in Meyerson and Reaser 2003) and is likely to increase the demand for resource managers to evaluate the perceived costs (impacts) versus benefits of invasive alien species to society (Perrings 2000, Pimentel 2003 or 2002?, Reaser et al. 2003b). Given the paucity of reliable quantitative information currently available for cost-benefit analyses, this task can be time consuming (if not impossible) and reduce the ability of resource managers to respond to invasive alien species soon enough to eradicate them. However, when the evidence of the impacts can be obtained and communicated reliably and rapidly, the information can motivate support from a wide range of constituencies (see examples in Veitch and Clout 2002 and discussion in section IV).

30. Differences in interpretation of the costs versus benefits of invasive alien species might also result in the failure of some constituencies to report the presence of invasive alien species and address the problem before the organisms have a significant impact. During the course of this assessment numerous publications were reviewed that did not report on the impacts of invasive alien species in island ecosystems that were known (through direct experience and other reliable resources) to be affected. For example, perhaps due to lack of awareness of the invasive alien species issue or choices not to report the problems, many of the authors in the annual *Status of Coral Reefs of the World* (Wilkinson 2002) do not mention invasive alien species as a threat to their coral reef systems, despite increasing evidence that reefs are both vulnerable to and are being detrimentally impacted by invasive alien species (e.g., Coles and Eldredge 2002, Eldredge and Carlton 2002, Eldredge and Reaser 2002, Hewitt 2002, Hutchings et al. 2002, Lambert 2002, Paulay et al. 2002, Smith, J.E. et al. 2002).

31. In the following section, case-studies are provided to illustrate the *ecological impacts* of invasive alien species on islands at the major levels of organization typically recognized by the Convention. Additional case-studies prepared by GISP and GISP-partners can be found in Meyerson and Reaser

(2003), as well as in Sherley (2000), Wittenberg and Cock (2001), Veitch and Clout (2002), MacDonald et al. (2003), Pallewatta et al. (2003), and Shine et al. (2003) (see also the *Thematic Reports on Alien Species* submitted by Parties to the Convention[11]). See Parker et al. (1999) for a review of the impacts of invasive alien species at five levels of biotic organization (individuals, genetic, population dynamics, community, and ecosystem process) across a variety of ecosystem types (mainland and island). The Convention's "Biodiversity Checklist" is provided in annex IV to illustrate the various levels and components of biodiversity that could be affected by invasive alien species.

32. *Genes*. Invasive alien species are sometimes introduced or spread into habitats that host closely related species. If the invasive alien species interbreed with the native species, the genetic makeup of one or both species can be altered. Multiple consequences are possible, including reduced survivorship (of either species), creation of a highly successful "super invader" (Rhymer and Simberloff 1996), or hybrids that are more susceptible to certain pathogens and become new hosts (hybrid bridge hypothesis; Floate and Whitham 1993). Whether the low genetic diversity of some island species makes them more susceptible to the impacts of invasive alien species remains to be shown (Loope and Mueller-Dombois 1989). See Rhymer and Simberloff (1996) for a review of hybridization and introgression between native and alien species. Levin et al. (1996) describe several cases of extinction by hybridization that occurred on islands.

33. *Case-study*: Mallard ducks (*Anas platyrhynchos*) are native to North America but have been introduced around the world, often for hunting purposes. There are numerous examples of hybridization between the mallard and other ducks that have resulted in reduced populations of native or endemic species. For example, hybridization with mallards has been detrimental to the New Zealand gray duck (*Anas superciliosa superciliosa*) and Hawaiian duck (*Anas wyvilliana*) (Rhymer and Simberloff 1996).

34. *Case-study*: Hybridization with invasive alien species may be a particularly significant threat to rare species on islands. Examples of rare island plants threatened by hybridization with invasive plants include: common butterwort (*Pinguicula vulgaris*) and yellow toadflax (*Linaria vulgaris*) in the British Isles, Canary madrona (*Arbutus canariensis*) on the Canary Islands, and Hawaiian ebony (*Gossypium tomentosum*) on the Hawaiian Islands (Levin et al. 1996).

35. *Species*. Invasive alien species can influence species diversity, richness, composition, abundance, and interactions (including mutualisms). The direct effects of invasive alien species at the species level occur through processes such as the predation of invasive alien species on, their competition with, and pathogen and parasite transmission to individual organisms (Wilcove et al. 1998, McNeely et al. 2001), eventually leading to population declines and resultant species extirpations and extinctions. While relatively few invasions have thus far resulted in species extinctions (Simberloff 1986, 2001), the number is certainly higher for islands than mainland systems (D'Antonio and Dudley 1995). The impact of predacious invasive alien species on island biota is particularly well documented and dramatic (e.g., Checke 1987, Johnson and Stattersfield 1990, see below). Species-level changes can also be induced by the impacts of IAS at other levels of biotic organization (see case-studies in other sections). In most instances where species-level changes are evident, however, little or no work has taken place to assess the consequences for habitats and ecosystem function (D'Antonio and Dudley 1995).

36. *Case-study*: A study of mammalian extinctions on Australian islands found that the presence of introduced foxes (*Vulpes vulpes*) and cats (*Felis catus*) correlated with native mammal extinctions, and that the cats were associated with extinctions particularly on more arid islands. Native mammals were most vulnerable to extinctions on islands that lacked significant rock pile habitat and in instances in which the species was large-bodied and restricted to the ground's surface (Burbidge and Manly 2002). See Burbidge and Morris (2002) for information on the eradication of mammals from Western Australian islands.

[11] http://www.biodiv.org/world/reports.asp?t=ais

37. *Case-study*: Brown trout (*Salmo trutta*) are aggressive and known to have negative impacts on a wide variety of native, freshwater species that inhabit rivers and streams. For example, in the Falkand Islands, brown trout seem to be restricting the distribution of and causing population declines in the native zebra trout (*Aplochiton zebra*) (McDowall et al. 2001). In New Zealand, the brown trout are predators of native galaxid fish and alter invertebrate behaviour. The impacts on these species have cascading effects throughout the ecosystem; grazing of algal films is suppressed, causing an increase in algal biomass and production and, consequently, an acceleration of nutrient uptake by algae. Ultimately, the trout are responsible for changes to energy and nutrient flux (Simon and Townsend 2003).

38. *Case-study*: In 1840, the Australian brushtail possum (*Trichosurus vulpecula*) was introduced to mainland New Zealand by acclimitasation socities, as well as individuals hoping to establish a fur industry. It was subsequently released on the neighboring islands (Pracy 1974). Studies conducted on the impacts of the possums on the native vegetation of Kapiti Island from 1969-1980 revealed that the possums increase defoliation, and sometimes mortality, of certain plant species (Atkinson 1992). The possums have also been shown to compete with insects and birds for food; prey upon eggs, chicks, and adult birds (Brown et al. 1993); and have contributed to the local extinction of the endemic bird known as the North Island kokako (*Callaeas cinerea wilsoni*; Innes et al. 1999). The possums have now been eradicated from Kapiti and other islands (Brown and Sherley 2002, Mowbray 2002).

39. Habitats. Through the impacts that invasive alien species have on species and ecosystem processes, their presence can lead to the fragmentation (see example from Christmas Island under ecosystems), destruction, and alteration (including complete replacement) of habitats. In turn, these impacts on habitats often result in impacts on even more species and ecosystem processes, leading to system-wide invasional ‘meltdown’ (Simberloff and Von Holle 1999, Mooney and Hobbs 2000, O’Dowd et al. 2003).

40. *Case-study*: Introduced mangroves (e.g., *Rhizophora mangle*) have had a significant impact on the native biota of Hawai’i, altering coastline hydrodynamics and nearshore sedimentation (i.e., ecosystem processes). The spread of mangroves has led to habitat loss for wetland birds, including the endemic Hawaiian stilt (*Himantopus mexicanus knudseni*), Hawaiian coot (*Fulica americana alai*), and Hawaiian duck (*Anas wyvilliana*). The mangrove habitats also provide refugia for shorebird predators, which include invasive rats (*Rattus* spp.) and the mongooses (*Herpestes* spp.), and non-native marine species, such as the mangrove crab (*Scylla serrata*) (Demophoulis and Smith 2001, see case study by A. Demopoulous in Meyerson and Reaser 2003).

41. *Case-study*: In 1937 a well meaning American professor introduced a large Andean tree known as *Miconia* (*Miconia calvescens*) to French Polynesia. Since that time, it has significantly altered the forests of French Polynesia and other Pacific islands. Its large leaves (up to 75 cm) make it capable of shading out all native plants and its shallow roots promote erosion and landslides. Each mature tree can produces millions of tiny seeds per year that are easily spread by birds, on construction equipment, or on someone’s hiking boots, thus enabling the species to spread rapidly through the landscape. By the 1980s, *Miconia* dominated 70% of the forest on Tahiti and has also invaded the neighbouring island of Moorea. It was reported in Hawaiian watersheds in the 1960s, but because management measures were not initiated until the 1990s, control of the plant now poses a formidable challenge (see comments by L. Loope in Shine et al. 2003).

42. *Case-study*: In the Galápagos archipelago, the plant species introduced since the island’s discovery in 1535 (600 spp.) now outnumber the native flora (500 spp.). The arrival of this alien flora equates to a rate of more than one species per year, while the natural rate of arrival of new plant species on the islands is about one species every 10,000 years. The alien plants are primarily cultivated species, but also include plants brought in unintentionally. By 2001, 55% of the alien species did not appear to be establishing, but 45% had naturalized. Of the latter, 7% are invasive, and 20% are potential invasives (Magee et al. 2001). Many of the invasive alien species (esp., trees, scrambles, climbers, and grasses) are

aggressively out-competing the Galápagos' endemic and native plants, altering the unique habitats that host numerous endemic animal species (Tye et al. 2002). Quinine tree (*Cinchona pubescens*), air plant (*Bryophyllum pinnatum*), multicolored lantana (*Lantana camara*), elephant grass (*Pennisetum purpureum*), guava (*Psidium guajava*), and hill raspberry (*Rubus niveus*) are among the worst invaders, and the four human-inhabited islands are the most significantly affected (McCullen 1999). For information on plant eradication programmes in the Galápagos, see Tye et al. (2002).

43. *Ecosystems*. Ecosystem effects can be especially difficult to measure (Mack and D'Antonio 1998). On islands (and in other ecosystems) known ecosystem-level impacts of invasive alien species include the alteration of trophic structure, shifts in the demands on resources (e.g., water, nutrients), alteration of resource availability or rates of resource renewal, and changes in the disturbance regime of an ecosystem (D'Antonio and Dudley 1995, O'Dowd et al 2003). The direct changes in trophic structure resulting from invasive alien species occur more often or with greater severity on islands than on continents because islands typically have poorly represented groups of organisms (esp., predators and large herbivores) (D'Antonio and Dudley 1995).

44. Large-scale and perhaps irreversible ecosystem alterations can occur when one invader facilitates the invasion or compounds the impacts of other invasive alien species. For example, on islands in particular, native tree species may be less vulnerable to natural disturbances such as cyclones and hurricanes than invasive alien species. Thus, when these disturbances occur in invaded landscapes, soil erosion, evaporation rates, and other ecosystem processes can be altered for prolonged periods (or permanently if the site is recolonized by invasive alien species, which is often the case) (see comments by J. Mauremootoo in Meyerson and Reaser 2003). In Hawai'i, the introduction of earthworms and certain introduced plants (e.g., *Psidium cattleianum* and *Passiflora mollissima*) facilitated the feralization of pigs (*Sus scrofa*) (Stone and Loope 1987), and the pigs' digging habits exposed mineral soils that enabled numerous plants to invade forest understories (Loope and Mueller-Dombois 1989).

45. *Case-study*: On tropical islands around the world, the fire cycle has commonly been altered by invasive alien species. Throughout the islands of Oceana, for example, introduced grasses have promoted fire when their dead litter accumulates as fuel. Consequently, the disturbance effect of fires, often increases the possibility for reinvasion by the invasive alien species previously established or by new invasive alien species (some of which might have been introduced for erosion control or restoration efforts). For example, several species of grasses were introduced to the Hawaiian islands as forage for cattle. Some of the grasses spread into woodlands, where they caused a 300-fold increase in the extent of fire (D'Antonio and Vitousek 1992, D'Antonio 2000).

46. *Case-study*: Introduction of the yellow crazy ant (*Anoplolepis gracilipes*) and other invasive alien species has had cascading effects throughout the ecosystem of Christmas Island, south of Java. The island has been well known internationally for its dense populations (1 per m^2) of native land crabs (*Gecarcoidea natalis*), which migrate to the ocean annually and are dominant consumers of rainforest detritus (Green et al. 1999). The yellow crazy ant was unintentionally introduced between 1915 and 1934, but has spread rapidly in the last decade. It is continuously active, has a broad diet, and tends honeydew-producing scale insects (*Tachardina aurantiaca*), causing their populations to explode in the forest canopy. The ants kill the crabs by "mobbing" them and spraying them with formic acid. As a result of the loss of crabs, large amounts of leaf litter accumulate, causing rapid changes in the entire ecosystem (because nutrients are no longer cycling through the soil as quickly). The ant has indirect effects on other forest processes as well; sooty molds growing on honeydew covered leaves, decrease photosynthesis and thus lower tree survival. Some data show that the ant is also affecting the reproductive success of endemic fruit-eating birds such as the Christmas Island thrush (*Turdus poliocephalus erythropleurus*), either through direct predation, habitat alteration, or competition for food (O'Dowd et al. 2003, see also comments by D. O'Dowd in Meyerson and Reaser 2003). Similar impacts are emerging in the Seychelles and Tokelau.

47. *Case-study*: Pollination and seed dispersal are essential process for both native and introduced plants (including crops). Some island plants (e.g., the silverswords; *Argyroxiphium–Dubasutia*) have evolved obligate outcrossing mechanisms and are thus threatened by impacts on their pollinators (Carr et al. 1986). The highly aggressive Argentine ant (*Iridomyrmex humilis*), for example, threatens to eliminate the Hakeaka silversword (*Argyroxiphium sandwicense macrocephalum*) in Hawai'i.

48. The ecological impacts that invasive alien species have on island ecosystems influence the ability of these ecosystems to provide the goods and services needed, or desired, by people. Invasive alien species can also have *socio-economic impacts* when they directly affect human health or physical structures (e.g., clog intake valves on power plants). The following section, includes case studies of the socio-economic impacts of invasive alien species (see paragraph 21 for list of other relevant sources of case-studies).

49. *Case-study*: Fisheries. The mud blister worm (*Polydora websteri*) can affect the oyster aquaculture industry by impacting the health of oysters and thus their marketability. The worm drills into the shells of living oysters and other mollusks, creating a small, mud-filled pocket that looks like a blister on the inner surface of the shell. The worms were found in an oyster farm at Kahuku, Oahu, Hawai'i, having been unintentionally introduced with oysters transported from Kaneohe Bay, Hawai'i or from fisheries on the western coast of the United States. They established in the oyster farm's cement holding tanks and eventually put the industry out of business (Bailey-Brock and Ringwood 1982, see comments by L. Eldredge in Meyerson and Reaser 2003).

50. *Case-studies*: Agriculture. Amami Island (710 km^2) is part of the Ryuku Archipelago in south-western Japan. It is primarily (70%) forested and hosts numerous endemic and threatened species (Kagoshima Prefecture Office 1999). Thirty small Indian mongooses (*Hespestus javanicus*) are believed to have been taken from Okinawa Island (Kishida 1931, Sekiguchi et al. 2001) in 1999 and released on Amami to control a highly venomous native snake known as the habu (*Trimeresurus flavoviridis*). Within 20 years, the mongoose population had reached 5,000-10,000 individuals and the range was extending at approximately 1 km per year (Environmental Agency 1999). This invasive alien specie has had profound impacts on agriculture (e.g., taro, sweet potato, watermelon) and the poultry industry, as well as biodiversity. The economic costs of damage to agriculture have risen from US$7,000 in 1994 to as high as US$110,000 in 1997. For additional statistics and information on mongoose control on Amami, see Yamada (2002).

51. The golden apple snail (*Pomacea canaliculata*) was intentionally introduced into Taiwan from Argentina in 1981 in order to enhance human health and economic development opportunities. It was believed that the snail would serve as a high-protein food source for local populations and as an export commodity for high-income countries. Instead, the snail moved into Asia's rice production system where it fed voraciously on young rice plants and spread through irrigation networks. The snail is now the primary rice pest in the Philippines. Naylor (1996) estimated that the cumulative (present-value) costs of the snail invasion to Philippine rice agriculture in 1990 were between US$425 million and US$1200 million, even without taking into account non-market damages such as impacts on ecosystems and human health. The golden apple snail and its relatives currently pose a problem on many islands in Asia and in the Pacific (see comments by L. Eldredge in Meyerson and Reaser 2003, case studies in Pallewatta et al. 2003 and Shine et al. 2003).

52. *Case-study*: Ornamentals. An invasive cut throat coral (*Carijoa riisei*), which looks like snow flakes when the white polyps are out, has recently started taking over black coral (Antipatharia) in Hawai'i. It has the potential to cause numerous ecological impacts in both shallow and deep water aspects of the reef system, and is now of great concern to the community of Maui and the black coral industry (valued at US$30 million annually). The invasive coral was discovered in Pearl Harbor in 1972, and is believed to have been transferred from the Caribbean on the hulls or in the ballast water of ships between 1940 and 1970 (Grigg 2003).

53. *Case-study*: Infrastructure. The Formosan subterranean or ground termite (*Coptotermes formosanus*) was officially recorded in Honolulu, Hawai'i in 1913, but might have been present as early 1869. It was likely introduced from Formosa or South China during the period when there was extensive trade in sandalwood between the Kingdom of Hawai'i and China. In spite of its relatively limited distribution, the Formosan subterranean termite is by far the most economically damaging pest in Hawai'i; the cost to prevent or control infestations and to repair the damage has been conservatively estimated at more than $60 million a year[12].

54. *Case-studies*: Tourism. In 1995, Norway rats (*Rattus norvegicus*) reached Fregate Island, the Seychelles' last remaining rat-free island greater than 100 ha in area. The island is a principle refuge for two birds, three invertebrates, and a mollusc endemic to the Seychelles. It also supports the largest populations of six species of endemic reptiles. Five years after the arrival of the rats, the commercial tourist industry became so worried about economic losses that a rat eradication programme was initiated. The flightless giant tenebrionid beetle (*Polposipes herculeanus*) was also facing its impending extinction at the time from the same invasive alien species, but did not garner nearly as much public attention as the loss of tourist income (Parr et al. 2000). For information on the eradication of rats on the island, see Merton et al. (2002). Tourism has also been threatened on the Seychelles' Bird Island, where the yellow crazy ant (*Anoplolepis gracilipes*) displaced ca. 60,000 pairs of sooty terns (*Sterna fuscata*), a main tourist attraction and economic mainstay of the island (Feare 1999).

55. The coqui (*Eleutherodactylus coqui*) is a small tree frog (2.5 cm in length) native to Puerto Rico were it is regarded as a symbol for the territory and its image adorns a wide variety of products intended for sale to tourists. The species arrived in Hawai'i in the late 1980s, probably imported on plants from the Caribbean or Florida that were intended for use in landscaping. The frog has since spread through the main Hawai'i Island and Maui. While the frog is capable of devouring huge numbers of endemic insects (possibly causing some extinctions) and thus competing with native birds, many Hawaiian citizens and tourists are much more upset (and regularly complain) about the very loud, piercing calls that the tiny frog makes at night (Staples and Cowie 2001, see comments by L. Loope in Shine et al. 2003)

56. *Case-study*: Human health. Several species of invasive snails are known to serve as intermediate hosts of the rat lungworm (*Angiostrongylus cantonensis*) which can cause the fatal disease eosinophilic meningoencephalitis in humans. Both the golden apple snail (*Pomacea canaliculata;* see case study under agriculture) and the giant African land snail (*Achatina fulica*) should be of concern to many island communities in the Asia-Pacific region. The latter has been both intentionally (as a potential food source) and unintentionally (contaminant of military equipment associated with World War II, horticulture, tiles) introduced. Despite the risk to humans, both species are commodities in the pet and aquaria trade.

57. *Case-study*: Animal health. The Australian brushtail possum (*Trichosurus vulpecula*), introduced to mainland New Zealand (see case study in paragraph 19), poses a considerable economic threat to the country through transmission of bovine tuberculosis to cattle and deer. As a result, millions of dollars are spent every year to control and eradicate the possums and thus the disease (Clout 1999).

58. *Case-study*: Cultural heritage. Invasive alien species can have significant impacts on various aspects of the cultural resources and heritage of island communities. The Alliance for the Heritage of East Maui, for example, recognizes invasive alien species as threats to both the environment and their culture, and is particularly concerned about the impacts of the golden apple snail (*Pomacea canaliculata*) and *Miconia* (*Miconia calvescens*).[13] In French Polynesia, *Miconia* has invaded cultural sites, causing stone walls to rupture (R. Mack, personal communication).

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[12] http://pesticides.hawaii.edu/studypackets/termite.html

[13] http://www.eastmauiheritage.net/yourtown-sum.shtml

59. *Case-study*: Governance. The pink hibiscus mealy bug (*Maconellicoccus hirsutus*) attacks more than 200 kinds of plants and is a serious pest in many tropical and subtropical regions, including Africa, southeast Asia, and northern Australia. It invaded Grenada in 1994 through an unintentional introduction. The insect caused US$18.3 million in losses to the agriculture industry and has cost more than a US$1 million to control. It has been strongly suggested that the government in power at the height of the infestation lost power because it was too slow to respond to the problem (see comments by M. Kairo in Meyerson and Reaser 2003). The bug has since spread to Guyana in South America, at least 14 additional Caribbean Islands, and reached Florida (USA) in 2002.

60. *Case-studies*: Costs. Prevention is by far the most cost effective means to minimize the spread and impacts of invasive alien species. If, however, prevention systems are not adequate and newly introduced IAS are not detected and eradicated before they spread and establish, the costs of reactive management can become quite high and require funds that might have been used to meet other societal needs. The following are examples of the costs of eradication and control of invasive alien species on islands:

(a) The Mediterranean fruit fly (*Ceratitis capitata*) was documented in New Zealand in 1996 and was eradicated at the cost of approximately NZ$6 million (Allwood et al. 2002).

(b) Eradication and control of an invasive grass (*Cenchrus echinatus*) on a seabird refuge on the remote island of Laysan (Central Pacific Ocean) has cost an average of US$150,000 per year (Flint and Rehkemper 2002).

(c) A project to eradicate feral goats from Lord Howe Island, a 1455-ha World Heritage Site off the coast of eastern Australia, by conducting hunts via helicopter (50 hours) and on the ground with dogs (220 hunter-days) was estimated to cost NZ$107,000. The campaign lasted for approximately five weeks, but was not completely successful. An annual control campaign has been estimated to cost NZ$6,000 (Parkes et al. 2002).

(d) The Institute for Wildlife Studies estimated that their costs for removing feral pigs from Santa Catalina Island (off the coast of California, USA) between 1990-September 2001 amounted to US$3,175,517 (Schuyler et al. 2002).

(e) The initial stages of a rapid response programme for the yellow crazy ant (*Anoplolepis gracilipes*) in Christmas Island National Park (incorporating impact analysis, islandwide surveys, development of control technology, broadcasting of bait by helicopter, and monitoring) has cost AUD$1.5 million over 2002-2003 (M. Jeffrey, Parks Australia, personal communication).

(f) In Hawaii, an intentionally introduced algae (*Hypnea musciformis*) has spread to several islands. On Maui, 9,000 kg of algae wash up on Kihei beaches per week, costing more than US$100,000 per year to clean. In total, algal biomass costs north Kihei more than US$20 million per year in loss of rental income, decrease in property value, and clean up (see comments by L. Eldredge in Meyerson and Reaser 2003).

61. The impacts that invasive alien species have on islands are almost never exclusively ecological or socio-economic. Ecological impacts translate into socio-economic impacts when they influence the ability of ecosystems to provide goods and services for humanity. Some species have direct impacts across a variety of ecological features and socio-economic sectors.

62. *Case-studies*: The brown tree snake (*Boiga irregularis*) is native to eastern Indonesia, the Solomon Islands, New Guinea, as well as the northern and eastern coasts of Australia. It was first sighted in Guam in the early 1950s, having probably arrived amidst ship cargo from a small island (Manus) in the Solomons. Within 30 years it had spread throughout Guam's 549 km^2 and up to 5,000 snakes can now be

found per square kilometre in some forested areas. The snake has decimated nearly all the native birds on the island; only 3 of 12 native bird species survive in the wild and one is on the verge of extinction (Savidge 1987). It has also severely impacted small reptile and mammal populations, including the threatened Mariana fruit bat (*Pteropus mariannus*). The arboreal snakes often move along power lines, frequently causing power outages, damaging equipment, and consequent problems ranging from food spoilage to computer failure. In addition to wildlife, snakes eat poultry, eggs, and pets. They will also attack humans and are reported to have attacked children in homes (Fritts 2000, see comments by M. Pitzler in Shine et al. 2003). For information on snake eradication see Rodda et al. (2002).

63. From both an ecological and socio-economic perspective, ants are probably the most harmful group of invasive insects on islands. The red imported fire ant (*Solenopsis wagneri* = *invicta*), originally from South America, has recently established in California and Australia and has been unintentionally spread from Florida across the Bahamas and Puerto Rico to Trinidad. The species is a threat not just to biodiversity, but to human health (stings), electrical equipment, agriculture, and ultimately to human quality of life in island environments. In Australia, a national eradication campaign for this ant is underway and the state of California is currently trying to contain (if not eradicate) the fire ant. However, it is poised to invade Hawai'i and other Pacific islands. The species is likely to prove especially damaging in archipelagos where the native fauna does not include ants (see comments by L. Loope and written statement on the red important fire ant in Shine et al. 2003).

D. Responses

64. The vulnerability of island ecosystems to the impacts of invasive alien species has led some resource managers to consider the protection and restoration of islands an impossible task. Islands and the human communities that depend upon them have often been neglected and occasionally decimated as a result (Loope and Mueller-Dombois 1989). However, there are a growing number of examples of successful invasive alien species eradication and control programmes on islands, and greater awareness of the problem is increasing the capacity of countries to prevent the movement and introduction of invasive alien species. Furthermore, it has become clear that the relatively small size and contained nature of terrestrial island ecosystems can present opportunities for the management of invasive alien species that are better than mainland ecosystems (Veitch and Clout 2002).

65. In general, the strategies that any government needs to have in place in order to minimize the impacts of invasive alien species are well known. The following resources provide guidance for developing and implementing effective, strategic programmes for the prevention, eradication, and/or control of invasive alien species. Several of them provide case studies or provide suggestions for overcoming socio-political, financial, scientific, technical, and technological challenges to the implementation of invasive alien species prevention and management programmes. Annex V provides additional guidance and resources that can help the Parties to the Convention and other stakeholders minimize the impacts of invasive alien species on island ecosystems in particular:

(a) Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species (CBD Decision VI/23)[14].

(b) Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species (IUCN 2000)[15].

(c) Global Strategy on Invasive Alien Species (McNeely et al. 2001).

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[14] http://www.biodiv.org/decision/defaults.asp?lg=dec=VI/23.

[15] http://www.issg.org/IUCNISGuidelines.html#Guidelines.

(d) A Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species (Shine et al. 2000). Includes information on agreements relevant to SIDS generally, as well as regional island groups.

(e) Invasive Alien Species: A Toolkit of Best Prevention and Management Practices (Wittenberg and Cock 2001). Includes case studies specific to islands.

(f) Invasive Species in the Pacific: A Technical Review and Draft Regional Strategy. (Sherley 2000).

(g) Turning the Tide: Eradication of Invasive Species (Veitch and Clout 2002). Proceedings of the International Conference on Eradication of Island Invasives. Exclusively focused on island issues.

(h) Results of an Experts Consultation on the Ecological and Socio-economic Impacts of Invasive Alien Species on Island Ecosystems (Meyerson and Reaser 2003).

66. Any plan to eradicate or control invasive alien species on islands (or other ecosystems) needs to consider the potential impacts of the proposed actions on island ecosystems and the people that depend upon them. If undertaken without an adequate consideration to ecosystem linkages, eradication and control programmes can create additional problems and lose their necessary public and institutional support as a result. For example:

(a) If not species-specific or properly handled and applied, some pesticides can threaten animal (wild and domestic) and/or human health. For example, an attempt to eradicate rats from Fregate Island in the Seychelles was abandoned when several critically endangered Seychelles magpie-robins died from secondary rodenticide poisoning (Thorsen et al. 2000). Accidental spillage of tonnes of the toxin Brodifacoum into nearshore waters in New Zealand occurred when the pesticide was being transported for use in a rat eradication programme on Campbell Island[16].

(b) Although purposeful introductions of organisms for biological control have led to notable successes in controlling invasive alien species on islands (Waterhouse 1989, Smith et al. 2002a,b), biocontrol agents have occasionally become invasive. Examples include the rosy wolf snail (*Euglandina rosea*) on Pacific islands (Hadfield et al. 1993, see also case study in Meyerson and Reaser 2003) and alien parasitoids in Hawai'i (Henneman and Memmott 2001). The cactus moth (*Cactoblastis cactorum*) was introduced to control *Opuntia* cactus in the Caribbean but has spread northward and is very likely to reach Mexico, the center of cactus diversity (Soberon et al. 2001). The science of biocontrol and governing regulations have, however, been considerably strengthened in recent years (Wittenberg and Cock 2001).

67. The invasion of alien species is a consequence of human activities and an issue that affects all sectors of society. People thus need to be recognized as both the facilitators of the problem and the means by which solutions can be achieved (McNeely 2001). Because of the relatively small size of the human populations on some islands and the community-based structure typical of many SIDS, island systems provide scientists, natural resource managers, and policy makers with particularly important and strong opportunities to engage indigenous and local communities in programmes to minimize the impacts of invasive alien species.

E. Conclusions

Action will remove the doubt that theory cannot solve. Tehyi Hsieh

[16] see http://www.hsno.govt.nz/events/p010523a.html

68. The process of biological invasion is complex and fraught with uncertainties. It is, thus, a challenge for ecologists, economists, and other scientists to develop and implement rigorous risk analysis frameworks and environmental impact assessments for invasive alien species. Furthermore, because the issue of invasive alien species is new to many sectors and governments, there is a paucity of data to incorporate into appropriate analyses. For these reasons, it can be very difficult to project the vulnerability of an island ecosystem to invasive alien species, as well as to determine the impacts that invasive alien species may have had or that may be in progress. Nevertheless, studies that are available lead experts to conclude that invasive alien species are now the most significant drivers of population declines and species extinctions in island ecosystems. Clearly, invasive alien species can also have significant socio-economic impacts either directly (e.g., on human health) or indirectly through their effects on ecosystem goods and services. Failure to adequately prevent and minimize the impacts of invasive alien species will undoubtedly result in a "piling up of new human difficulties" (Elton 1958).

69. The response measures needed to prevent and minimize the impacts of invasive alien species on island ecosystems are generally known. However, many island nations and territories lack the scientific and technical information, infrastructure, and human and financial resources necessary to adequately address the problems caused by invasive alien species. This is not just a problem facing the developing world or one that the developing world should be facing alone. Because every country is an exporter and importer of goods and services, every country is also a facilitator and victim of the invasion of alien species. The patterns and trends of invasion have and will continue to follow the patterns and trends of international commerce and the movement of people. Furthermore, the process of biological invasion and the severity of its consequent impacts are likely to be facilitated by land use and climate change. Every country, even the most economically wealthy, therefore, needs to raise the capacity of island nations and territories to minimize the spread and impact of invasive alien species.

70. Although the prevention, eradication, and control of invasive alien species on islands (and in other ecosystems) present scientific, political, and ethical challenges, the problem can be dramatically reduced through concerted action. Stakeholders need to be made aware of the problem and motivated to address it. Scientifically-based information and effective tools need to be provided to policy makers and resource managers so that well-informed decisions can be enacted. Co-operative programmes need to be forged among governments and other institutions to enable the problem to be addressed in a strategic, holistic, and timely manner.

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Annex I

ECOLOGICAL AND SOCIO-ECONOMIC FACTORS THAT INFLUENCE THE RISK OF INTRODUCTION, ESTABLISHMENT, AND SPREAD OF IAS IN ISLAND ECOSYSTEMS

Notes: This table provides examples of relevant factors and is not an exhaustive list. Each species and island will be influence by a unique set of factors, many of which will be inter-related. Many of the ecological and socio-economic factors listed can contribute to or result from environmental disturbances. Mueller-Dombois (1981) found that disturbance is an important determinant of species invasion than climate, although climate can play an indirect role.

Factors	***Introduction***	***Establishment***	***Spread***
Ecological	Species vagility (capability to move) or transportability (including ability to survive transit)		Species vagility (capability to move) or transportability
	Ability to escape into the environment (unintentional introductions)	Climate (and the stochasticity within climate)	Climate (and the stochasticity within climate)
		Resource (food, habitat, etc.) availability	Resource (food, habitat, etc.) availability
		Ability to avoid predation, competition, pathogens and parasites	Ability to avoid predation, competition, pathogens and parasites
		Ability to produce viable offspring	Ability to produce viable offspring
		Ability to establish mutualisms	Ability to establish mutualisms
Socio-economic	Demand for goods and services (esp. imports)	Demand for goods and services (i.e. cultivation or animal husbandry)	Demand for goods and services (i.e., tendency for cultivation or animal husbandry)
	Modes, frequency, capacity and, routes, along pathways (Annex 2 below)	Existence of effective IAS early detection programmes	Types, routes, timing of pathways (Annex 2 below)
			Timing of IAS detection and response
			Methods used for eradication or control, as well as timing and scale the response to invasion

Annex II

COMMON AND LIKELY PATHWAYS FOR THE INTRODUCTION OF INVASIVE ALIEN SPECIES TO ISLANDS

Note: This table summarizes the major known and likely pathways for the invasion of alien species into island ecosystems. It is not a complete list of invasive alien species pathways for islands or other ecosystems. Each island will have a unique set of pathways that are likely to change over time.

Pathway	***Means of Introduction*** [17,18]	***Examples***
Terrestrial		
Products & Supplies	1. (U) Organisms moved on non-living imports, in shipping containers, and/or on ships or planes and escape into the environment. Likely the most significant pathway for islands at this time and into the future	1. A brown tree snake (*Boiga irregularis*), a serious problem for ecological and socio-economic systems, was first sighted in Guam in the early 1950s. It likely arrived amidst ship cargo from a small island (Manus) in the Solomons and has since been transported in the wheel wells of airplanes (Fritts 2000, see comments by M. Pitzler in Shine et al. 2003). Numerous terrestrial insects are known to move in sea cargo containers (Stanaway et al. 2001)
Tourism (& other human movement)	1. (U) Organisms moved on people (esp. shoes) and their property (luggage etc.) and escape into the environment	1. Since being discovered in 1961, the sandbur, *Cenchrus echinatus*, an annual grass native to Central America, has become a serious problem on Laysan Island, a Hawai'ian National Wildlife Refuge. Scientists believe that the grass was introduced to the island on the clothing or in the equipment of military or research personnel (Flint and Rehkemper 2002)
Food and Other Natural Resources (provisioning)	1. (I/U) Animals (esp. pigs and goats) released and plants introduced to ensure food supplies. Inadvertent introductions also occurred when animals escaped from ships or when ships wrecked. Historically, very important pathway, especially during times of exploration and military activities. Can facilitate introduction of associated organisms (pathogens, seeds, etc.)	1. The Polynesians brought 40-50 species of animals and plants when they colonized Hawai'i (Kirsh 1982, Nagata 1985), averaging 3-4 introductions per century for a period of about 1400 years (Loope and Mueller-Dombois 1989). The Pacific rat (*Rattus exculans*) arrived in New Zealand with Polynesian travellers, perhaps as long as

[17] (I): Intentional introduction. Refers to the deliberate movement and/or release by humans of an alien species outside its natural range. (U): Unintentional introduction. Refers to all other introductions which are not intentional.

[18] In most cases, the introduction of biological organisms does not create a problem; either the organisms do not survive in their new conditions without deliberate cultivation and husbandry or their populations are small and easily managed (Mack 2000, Mack et al. 2000). One study estimates that 1 out of every 1000 organisms introduced into a new environment thrives and becomes invasive ("The Tens Rule;" Williamson and Brown 1986, Williamson 1996).

		2000 years ago. It was used as a food source and introductions were likely both intentional and unintentional (Thomas and Taylor 2002). Seeds of various grasses were probably introduced intentionally and unintentionally in order to supply material for reed boats (Heyerdahl 1985)
Food (agriculture & livestock)	1. (I/U) Plants and animals propagated for local use and export (in some cases). Potential for these and their associated organisms to escape into the surrounding environment 2. (I/U) Plants and their associated organisms introduced to enhance agriculture production or provide forage for livestock	1. Numerous examples mentioned herein. For lists in the Galápagos see McCullen (1999), and for Hawai'i see Staples and Cowie (2001) 2. Tropical kudzu (*Pueraria phaseioloides*), a plant native to Southeast Asia, was introduced to the Galápagos to fix nitrogen and as a forage plant. It is considered a "noxious weed" and is closely related to the highly-invasive *P. lobata* (Soria et al. 2002). Several species of grasses were introduced to the Hawai'ian islands as forage for cattle. Some of the grasses spread into woodlands, where they cause a 300-fold increase in the extent of fire (D'Antonio and Vitousek 1992)
Game	1. (I/U) Animals (esp. mammals) released to provide stock for hunting and trapping (for food, products, or recreation). Includes possible introduction of associated organisms	1. The Australian brushtail possum (*Trichosurus vulpecula*) was introduced into New Zealand in 1840 for fur harvesting. It has since become a significant threat to native biota (Brown and Sherley 2002).
Aesthetics (landscaping & water gardening)	1. (I/U) Plants and animals (e.g. fish) introduced to create attractive gardens (may particularly be a problem in areas of high tourism). Includes possible introduction of associated organisms	1. The coqui (*Eleutherodactylus coqui*) is a small tree frog (2.5 cm length) native to Puerto Rico with a loud, piercing call. It arrived in Hawai'i in the late 1980s, probably on plants intended for landscaping that were imported from the Caribbean or Florida. It has since spread through the main Hawai'i Island and Maui (Staples and Cowie 2001, see comments by L. Loope in Shine et al. 2003)
Pest Control	(I/U) Release of organisms as biological control agents. Includes their associated organisms	1. Thirty small Indian mongooses (*Hespestus javanicus*) are believed to have been taken from Okinawa Island and released to Amami Island to control a highly venomous native snake known as the habu (*Trimeresurus flavoviridis*). The economic costs of mongoose damage were

		US$110,000 in 1997(Yamada 2002)
Erosion Control	1. (I/U) Introduction of alien plants and their associates to reduce sediment loss 2. (U) Release of IAS associated with re-introduced or established native species	1. *Mimosa* (*Mimosa pigra*) is an invasive tree in many parts of the world. It is believed to have been introduced into Sri Lanka in order to stabilize river banks (Marambe et al. 2001)
Restoration	1. (I/U) Introduction of alien plants and their associates for habitat 2. restoration/conservation purposes 3. (U) Release of IAS associated with re-introduced or established native species	
Plant/Seed Exchange	1. (I/U) Trade of plants and seeds for botanical gardens and research collections. Plants are often intentionally introduced following trade. Associated organisms might be introduced as well	1. Exchange of seed material between countries, esp. through botanical gardens, has been one of the major pathways for the introduction of invasive plants into Sri Lanka (Marambe et al. 2001)
Freshwater		
Food (aquaculture)	1. (I/U) Release of organisms for propagation and harvest. Includes associated organisms 2. (U) Escape of stocks and/or their associated organisms from holding facilities/transport containers	1. The golden apple snail (*Pomacea canaliculata*) was intentionally introduced into Asia in 1980 to serve as a high-protein food source and an export commodity. It caused major damage to rice crops (Naylor 1996)
Fisheries & Game (recreational)	1. (I/U) Release of organisms for sporting purposes, including organisms intended to serve as their forage. Also includes associated organisms (e.g., pathogens that are unintentionally released) 2. (U) Escape of fisheries stocks, game species (e.g., frogs), and their associated organisms during transport, or during transplantation and holding for growth or refreshening (rejuvenation) 3. (U) Introduction of organisms associated with relocated fishing gear (e.g., lines, nets) 4. (I/U) Introduction of aquatic plants and associated material to enhance habitat fisheries/game stocks 5. (U) Release of organisms (esp. pathogens and parasites) from waste produced by processing of fish/game	1. Release of brown trout (*Salmo trutta*) into rivers and streams of New Zealand (Simon and Townsend 2003) and the Falkland Islands (McDowall et al. 2001) 2. Mallard ducks (*Anas platyrhynchos*) are native to North America but have been introduced around the world, often for hunting purposes. Hybridization between mallards and native species has been detrimental to the New Zealand gray duck (*Anas superciliosa superciliosa*) and Hawaiian duck (*Anas wyvilliana*) (Rhymer and Simberloff 1996).
Horticulture (water gardening)	1. (I/U) Introduction of plants, fish, and other organisms for propagation in natural and artificial water systems, largely for aesthetics. Includes associated organisms	1. Numerous invasive freshwater snails have been intentionally and unintentionally introduced to the Pacific islands (Cowie 2002)
Marine[19]		
Boats & Ships	1. (U) Organisms released when ships	1. Modern vessels may be

[19] For an overview of marine bioinvasions in the United States, see Carlton (2001).

(note: associated marinas etc. often serve as colonizing habitat making harbors recipients of and sources for IAS)	discharge ballast water 2. (U) Organisms attached to interior or exterior structures and equipment (e.g., anchors)[called "fouling organisms"] released into the environment	carrying between 3,000 and 10,000 species globally in any given 24 hour period in their ballast water. See Carlton (1999, 2001) for examples 2. In 1998, the USS Missouri introduced the Mediterranean mussel (*Mytilus galloprovincialis*) from Puget Sound to Hawai'i where it now reproduces in Pearl Harbor (Apte et al. 2000). See also comments by L. Eldredge and statement on hull fouling in Meyerson and Reaser (2003)
Dry Docks	1. (U) Organisms attached to structures are relocated 2. (U) Organisms released when ballast water is discharged or escape from	
Floating Debris	1. (U) Organisms moving on garbage (e.g., bottles, nets, packaging) relocated	1. Barnes (2002) regards garbage, especially plastics, as one of "best opportunities" for dispersal of marine IAS. See Donohue et al (2001) for information on discarded fishing gear as a pathway for IAS in the Northwestern Hawaiian islands
Fisheries (recreational)	1. (I/U) Release of live bait and associated organisms 2. (U) Escape of fisheries stocks (incl. shellfish) and their associated organisms during transport, or during transplantation and holding for growth or refreshening (rejuvenation) 3. (U) Introduction of organisms associated with relocated fishing gear (e.g., lines, nets, floats, trawls, dredges) 4. (U) Release of organisms (esp. pathogens and parasites) from waste produced by processing of fish	1. The Marquesan sardine (*Sardinella marquesensis*) was introduced into Hawai'i to establish a baitfish industry. Although the fish established, it never become a major baitfish. Mexican mollies (*Poecilia mexicana*) were imported to Samoa to develop baitfish industry which proved to not be economically sound (Eldredge, 1994)
Food and Other Natural Resources (mariculture)	1. (U) Escape of fish (including shellfish) stocks and their associated organisms from holding facilities/transport containers 2. (I/U) Organisms associated with food packaging (e.g., seaweed) released into the environment when packaging is discarded	1.The mud blister worm (*Polydora websteri*) was found in an oyster farm at Kakuku, Oahu, Hawai'i, having been unintentionally introduced with oysters transported from Kaneohe Bay, Hawai'i or the western coast of the United States. It eventually put the industry out of business (Bailey-Brock and Ringwood 1982, see comments by L. Eldredge in Meyerson and Reaser 2003). Tntentionally introduced Philippine seaweeds (*Kappaphycus alvarezil* and *K. striatum*) covers large areas of Kaneohe Bay coral reefs in Hawai'i, threatening biodiversity

		and the tourist industry (Woo et al. 2001) 2. Mariculture packaging material and bivalve spat is known to carry numerous species (Carlton and Ruckelshaus 1997) *For an overview of mariculture in the U.S. see Goldburg et al. (2001)
Water Sports (see also boats & fisheries)	1. (U) Introduction of organisms associated with relocated sporting gear (e.g., SCUBA tanks, rafts, inner tubes, surfboards)	
Buoys, Pots, and Floats	1. (U) Organisms attached to structures are relocated	

Annex III

RISKS OF SMALL ISLAND DEVELOPING STATES (SIDS) TO THE IMPACTS OF INVASIVE ALIEN SPECIES

Features of SIDS Leading to their Vulnerability to Environmental Problems (Kaly et al. 2002)	Particular Relevance to Risk of Impacts from Invasive Alien Species
Geographic isolation	• Limits the types of species reaching islands naturally (e.g., native large mammalian predators typically absent) • Leads to evolution of unique (thus rare) forms of species ("endemic species") on individual islands and island chains
Small physical size	• Limits range size of island species (concentrates organisms in small area) • Can limit population size and number of populations of a species
Ecological uniqueness and fragility	• Species that evolved without major predators, competitors, or a diversity of pathogens and parasites might be unable to survive the introduction of these organisms (i.e., results in high mortality) • The limited size of populations and population numbers, as well as species endemism, leads to extinction rates that are higher than continental systems
Rapid human population growth and high densities	• Leads to limited natural resources (see below)
Limited natural resources	• Leads to alteration of habitats in such a way that they become more susceptible to the establishment of IAS (e.g., regular disturbance) • Leads to local resource shortages and the demand for more imports (thus increasing the pathways for IAS) • Can result in human migration and movement (intentional and unintentional) of organisms to new locations
High dependence on marine resources	• Places constraints on local fisheries and can create demand for mariculture and aquaculture (which are often use non-native species), increasing likelihood that IAS enter the environment • Boating and shipping can lead to the introduction of IAS through hull and equipment fouling and ballast water discharge
Sensitive and exposed to extremely damaging natural disasters	• Leads to opportunities for frequent habitat disturbance and establishment of invasive plants (which are often rapid colonizers and strong competitors in disturbed systems) • Can create demand and desire for purposeful introduction of IAS for "restoration" and erosion control (plants are often chosen that grow fast and spread

	rapidly; i.e., characteristics typical of IAS)
Small economies with low diversification ("thinness")	• Can increase dependency on external markets (i.e., increase trade and thus pathways of invasion) • Can increase demand for economic development and diversification that is based on propagation of introduced plants and animals (e.g., ornamental and food aquaculture or mariculture), which might become invasive
Susceptible to climate change and sea level rise	• Will likely increase constraints on all other factors. For example, Chown et al. (2002) site interactions between IAS and climate change are the largest conservation threat to invertebrates of the sub-Antarctic Prince Edward Islands • See the following for reviews of IAS and climate change: Dukes and Mooney (1999), Mooney and Hobbs (2000); includes case study from New Zealand)
Poorly-developed infrastructure, limited capacity, funds and human resource skills.	• Leads to lack of awareness of the threats posed by IAS, and poor systems for the prevention (esp. quarantine), eradication (early detection and rapid response), and control of IAS.

Annex IV

"BIODIVERSITY CHECKLIST" OF THE CONVENTION: VARIOUS COMPONENTS OF BIODIVERSITY THAT COULD BE AFFECTED BY INVASIVE ALIEN SPECIES

See Appendix 4 of decision VI/7 (Identification, monitoring, indicators and assessments).
http://www.biodiv.org/decisions/default.asp?lg=0&dec=VI/7

COMPONENTS OF BIOLOGICAL DIVERSITY

Levels of Biodiversity	**Composition**	**Structure (temporal)**	**Structure (spatial: horizontal and vertical)**	**Key Processes**
Genetic diversity	• Minimum viable population (avoid destruction by inbreeding/ gene erosion) • Local cultivars • Living modified organisms	• Cycles with high and low genetic diversity within a population	• Dispersal of natural genetic variability • Dispersal of agricultural cultivars	• Exchange of genetic material between populations (gene flow)
Species diversity	• Species composition, genera, families, etc., rarity/ abundance, endemism/ exotics • Population size and trends • Known key species (essential role) • Conservation status	• Seasonal, lunar, tidal, diurnal rhythms (migration, breeding, flowering, leaf development, etc.) • Reproductive rate, fertility, mortality, growth rate • Reproductive strategy	• Minimal areas for species to survive • Essential areas (stepping stones) for migrating species • Niche requirements within ecosystem (substrate preference, layer within ecosystem) • Relative or absolute isolation	• Regulation mechanisms such as predation, herbivory, parasitism • Interactions between species • Ecological function of a species
Ecosystem diversity	• Types and surface area of ecosystems • Uniqueness/ abundance • Succession stage, existing disturbances and trends (= autonomous development)	• Adaptations to/ dependency on regular rhythms: seasonal • Adaptations to/ dependency of on irregular events: droughts, floods, frost, fire, wind • Succession (rate)	• Spatial relations between landscape elements (local and remote) • Spatial distribution (continuous or discontinous/ patchy) • Minimal area for ecosystem to survive • Vertical structure (layered, horizons, stratified)	• Structuring process(es) of key importance for the maintenance of the ecosystem itself or for other ecosystems

Annex V

GUIDANCE AND RESOURCES FOR PREVENTING AND MITIGATING THE IMPACTS OF INVASIVE ALIEN SPECIES ON ISLAND ECOSYSTEMS

CBD Guiding Principle[20]	Guidance/Comments	Resources[21]
1. Precautionary approach	• Raising the capacity of SIDS to conduct risk analyses and gain access to relevant information needs to become a priority for the development assistance community	• *Globalisation and IAS*[22] • *Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve*[23,24]
2. Three-stage hierarchical approach	• Preventative measures are particularly challenging to implement on islands because of their long, “open” shorelines and lack of adequate legal frameworks[25] • In island systems, priority needs to be given to preventing the movement of IAS along pathways of invasion (Annex 3), including efforts to minimize between island transfers of IAS within the same region	• See information on pathways in Annex 2 • See 13 • See gaps in knowledge in Meyerson and Reaser (2003)
3. Ecosystem approach	• Thus far, measures to deal with IAS have largely taken a species by species approach	• See 13
4. The role of States	• For island nations and territories, States need to give particular attention to their trading partners	• See Shine et al. (2003), Pallewatta et al. (2003), and MacDonald et al. (2003) for national reports on IAS in island nations • See *Thematic Reports on Alien Species*[26]
5. Research and monitoring	• Numerous information gaps exist for assessing, preventing, and mitigating the impacts of IAS on islands • Very few islands nations or territories have monitoring programmes for IAS • Voucher specimens should be deposited in well-managed collections	• See list of gaps in knowledge and research priorities in Meyerson and Reaser (2003) • *Hawaiian Ecosystems at Risk Project (HEAR)*[27]

[20] http://www.biodiv.org/decisions/defrault.asp?lg=0&dec=VI/23
[21] This is not an exhaustive list of resources, but is intended to provide information on the major “gateways” of information and examples of activities specifically directed IAS on islands.
[22] http://odin.dep.no/ud/norsk/publ/rapporter/032121-220009/index-hov006-b-f-a.html
[23] http://hawaiireef.noaa.gov/comment/sdcom/washdc.html
[24] http://www.oceanconservancy.org/dynamic/press/kits/owcKit/nwhi.pdf
[25] See comments by M. Kairo in Meyerson and Reaser (2003)
[26] http://www.biodiv.org/world/reports.asp?t=ais
[27] http://www.hear.org

6. Education and public awareness	• Historically, IAS have been seen as only an agricultural pest[28] • In 2001-2003, GISP led regional workshops (including SIDS) to raise awareness of the causes and multiple consequences of IAS • Education and public awareness needs to focus island inhabitants and visitors (i.e., tourists), as well as nations governing island territories • Because many island populations are small, virtually every person can be reached and educated about IAS[29] • The history of island cultures and governance will strongly influence people's relationships to the environment and IAS in particular[30]	• *The Cooperative Initiative on Invasive Alien Species on Islands*[31] • *Hawaiian Ecosystems at Risk Project (HEAR)*[32] • *Hawaii Biological Survey*[33] • *Guidebook of Introduced Marine Species of Hawaii*[34] • See 4 • For an example in Tonga, see Shine et al. (2003)
7. Border control and quarantine measures	• See 2	• See 2
8. Exchange of information	• See 6	• See 6 • *Pacific Basin Information Node*[35] • *Island Conservation Database*[36] • *The Global Invasive Species Database*[37] • *Centre for Research on Introduced Marine Pests*[38] • *FishBase*[39] • *Aquatic Invasions Research Database*[40] • *Plants Database*[41]

[28] See comments by M. Kairo in Meyerson and Reaser (2003)
[29] See comments by J. Mauremootoo in Meyerson and Reaser (2003)
[30] See comments by J. Mauremootoo in Meyerson and Reaser (2003)
[31] http://www.issg.org/islandIAS.html#IslandIAS
[32] http://www.hear.org
[33] "Good Guys/Bad Guys;" http://hbs.bishopmuseum.org/good-bad/index.shtml
[34] 2002. Hawaii Biological Survey, Bishop Museum. http://www2.bishopmuseum.org/HBS/invertguide/index.htm
[35] http://pbin.nbii.gov/invasives.asp
[36] http://128.114.44.155/pls/dbase/ISLA2.public_menu.show
[37] http://www.issg.org/database/welcome/
[38] http://crimp.marine.csiro.au/
[39] http://www.fishbase.org
[40] http://invasions.si.edu/aird.htm
[41] http://plants.usda.gov/

9. Cooperation, including capacity-building	• The need to overcome the particular challenges faced by island nations (esp. SIDS) and territories (Annex 3) makes programmes of cooperation particularly important	• *The Cooperative Initiative on Invasive Alien Species on Islands*[42] • *Island Conservation*[43]
1	•	•
10. Intentional introduction	• Historically, led to the most significant impacts • All other comments relevant	• All other resources relevant
11. Unintentional introduction	• Currently, likely to have at least as great, if not far greater, impacts • All other comments relevant	• All other resources relevant

[42] http://www.issg.org/islandIAS.html#IslandIAS

[43] Non-profit organization focused on prevention, eradication, and control of IAS on islands; http://www.islandconservation.org

12. Mitigation of impacts	• Due to their high-level of vulnerability to IAS, early detection and rapid response are particularly important in island ecosystems • The isolation and small size of many islands can provide opportunities for eradication and control of species in ways that would not be possible in mainland systems • There are numerous example of successful eradication, containment, and control of IAS in island ecosystems	• *Island Conservation*[44] • *Turning the Tide: Eradication of Invasive Species* (Veitch and Clout 2002) • See Sherley (2000)
13. Eradication	• See 12 • Studies indicate that there can be at least limited recovery of plant systems following the removal of invasive herbivores (e.g., Loope and Scowcroft 1985)	• See 12 • See also Simberloff (2001)
14. Containment	• See 12	• See 12
15. Control	• See 12	• See 12
