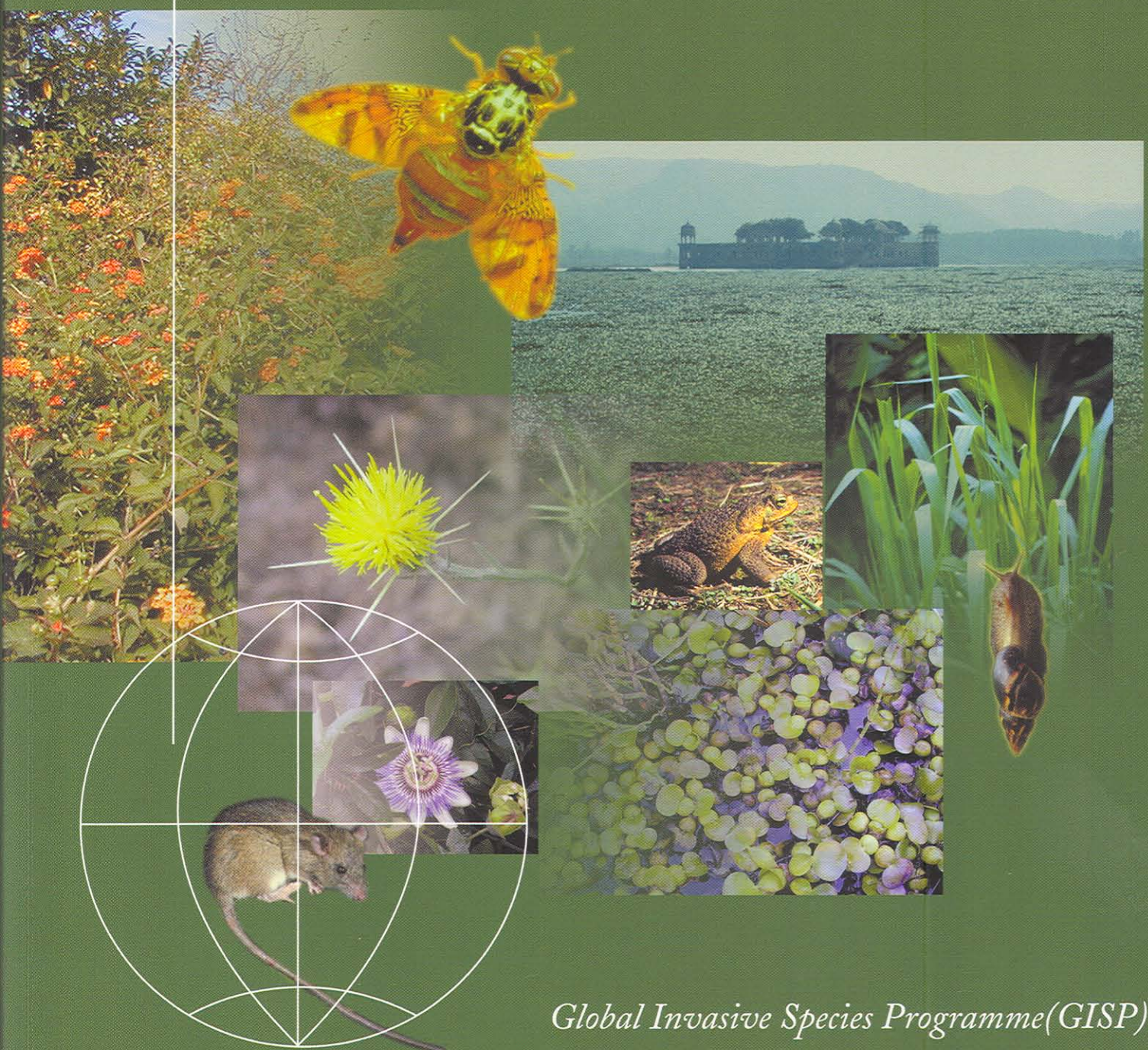
Global Strategy on Invasive Alien Species



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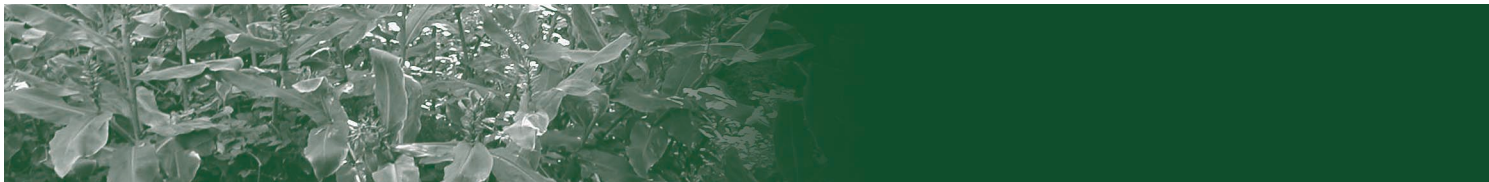

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Global Strategy on Invasive Alien Species

Edited by
Jeffrey A. McNeely, Harold A. Mooney, Laurie E. Neville, Peter Johan Schei and Jeffrey K. Waage

Global Invasive Species Programme(GISP)

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Front cover: Mediterranean fruit fly (*Agriculture Australia*); *Lantana* (*GISP Archive*); water hyacinth on Man Sagar Lake, near Jaipur, India (*Richard Mack*); Rat, Hawai'i, USA (*Jack Jeffrey Photography*); yellow star thistle (*Brousseau*); Zebra Mussel, USA (*C.O'Neill, Jr*); *Passiflora* spp, *Scalesia* spp. and giant African snail, Seychelles (*GISP Archive*). Back cover: Wildfire, South Africa (*The Argus*); Rosy Wolf Snail (*Jack Jeffrey Photography*); OMB, New Zealand (*R. Wittenberg*). Chapter headings: 1 - *Melaleuca* spp., 2 - Ship, 3 - Yellow Star Thistle (*Centaurea solstitialis*), 4 - *Ipomea* & *Cinnamomum* spp. (*GISP Archive*), 6 - mosquitos, Hawai'i, and 7 - Rat, Hawai'i (*Jack Jeffrey Photography*); references and annexes: *Achatina fulica*, *Passiflora* flower, *Scalesia* spp. (*GISP Archive*).

Preface

The Global Strategy on Invasive Alien Species is based on contributions from the team leaders of the eleven main components addressed under Phase I of the Global Invasive Species Programme. This strategy summarizes key findings of the Phase I Synthesis Conference held September 2000 in Cape Town, Republic of South Africa and presents ten strategic responses that address mitigating the threats of invasive alien species. Directed toward the decision-makers whose policies and practices are affecting the movement of species around the world, this Strategy strives to provide a resource to increase awareness and provide policy advice. GISP has produced other volumes for more specialized audiences; these volumes provide detailed information and guidance to those interested. These publications are listed in Annex 4.

This contribution is a collaborative effort of the Global Invasive Species Programme, derived from the products of the GISP Phase I Components. The Strategy was compiled by Jeffrey A. McNeely, with contributions from Mike Allsopp, Yvonne Baskin, Jesslyn Brown, Michael Browne, Mick Clout, Silvana Dalmazzone, Sarah Lowe, Harold Mooney, Robert Meese, Cynthra Persad, Guy Preston, Dave Richardson, Jim Space, Simon Stuart, Peter Schei, Jeff Waage, and Erik Wijkstrom. Useful input was received by D.A. Andow, Robert Bensted-Smith, James Y. Carlton, Maj de Poorter, Richard Hobbs, Alan Holt, Mark Lonsdale, Wayne Lotter, Sean Murphy, Laurie Neville, Charles Perrings, Jamie K. Reaser, Marcel Rejmanek, Greg Ruiz, Greg Sherley, Bernie Tershy, Nattley Williams, Charlotte Williamson, Mark Williamson, Rüdiger Wittenberg, and Erika Zavaleta.

The Global Invasive Species Programme (GISP) is coordinated by the Scientific Committee on Problems of the Environment (SCOPE), in collaboration with the World Conservation Union (IUCN), and CAB International (CABI). GISP has received initial financial support from the United Nations Environment Programme (UNEP) - Global Environment Facility (GEF), United Nations Education, Scientific and Cultural Organization (UNESCO), the Norwegian Government, the National Aeronautics and Space Administration (NASA), the International Council for Scientific Unions (ICSU), La Fondation TOTAL, the United States Department of State, Bureau of Oceans and International Environmental Affairs Initiative (OESI), the David and Lucile Packard Foundation, and the John D. and Catharine T. MacArthur Foundation. Participating groups and individuals have made substantial in-kind contributions. GISP is a component of DIVERSITAS, an international programme on biodiversity science.

Table of Contents

CHAPTER 6

Management and policy responses to the problem of invasive alien species

CHAPTER 7

Ten strategic responses to address the problem of invasive alien species

A Global Strategy on Invasive Alien Species

The spread of invasive alien species (IAS) is creating complex and far-reaching challenges that threaten both the natural biological riches of the earth and the well being of its citizens. While the problem is global, the nature and severity of the impacts on society, economic life, health, and natural heritage are distributed unevenly across nations and regions. Thus, some aspects of the problem require solutions tailored to the specific values, needs, and priorities of nations while others call for consolidated action by the larger world community. Preventing the international movement of invasive alien species and co-ordinating a timely and effective response to invasions will require cooperation and collaboration among governments, economic sectors, non-governmental organisations, and international treaty organisations. This strategy highlights the dimensions of the problem and outlines a framework for mounting a global-scale response. While both the problem and the scale of the solution may appear dauntingly complex, the issue presents an unparalleled opportunity to respond with actions that link preservation of biodiversity with protection of the health and livelihood of the world's human populations.

Invasive alien species are a threat to biodiversity and threaten food security, health and economic development.

The spread of Invasive Alien Species (IAS) is now recognised as one of the greatest threats to the ecological and economic well being of the planet. These species are causing enormous damage to biodiversity and the valuable natural agricultural systems upon which we depend. Direct and indirect health effects are increasingly serious and the damage to nature is often irreversible. The effects are exacerbated by global change and chemical and physical disturbance to species and ecosystems.

Continuing globalisation, with increasing trade, travel, and transport of goods across borders, has brought tremendous benefits to many people. It has, however, also facilitated the spread of IAS with increasing negative impacts. The problem is global in scope and requires international co-operation to supplement the actions of governments, economic sectors and individuals at national and local levels. IAS are found in nearly all major taxonomic groups of organisms. Even though only a small percentage of species that are moved across borders become invasive, these may have extensive impacts. These effects can be devastating; studies in the United States and India show that the economic costs of IAS in these countries amount to approximately US$130 billion per year.

Consolidated action for prevention of the spread of IAS is urgent.

Preventing introduction of potentially invasive alien species is by far the preferred strategy. To prevent spread, every alien species should be treated as potentially invasive unless and until convincing evidence indicates that this is not so. For deliberate introductions it is recommended that standardised risk analysis (RA) and risk management procedures (RMP) be developed, perhaps based on the RA and RMP developed under the Cartagena Protocol of the CBD. Preventive measures must be taken at both the source and the destination of the invasion.

For inadvertent introductions, new and innovative strategies and actions must be developed in cooperation with the trade, travel, tourism and transport sectors. Awareness raising, legislation, information, management, education and training are essential areas to address. Harmonised standards for preventive measures in practical operations in each economic sector should be developed at the international and national level. Cross-sectoral coordination and

cooperation are imperative. Mechanisms, procedures and regulatory measures for achieving synergies and efficiency are key strategic tools for achieving the goal of national biosecurity. The authorities responsible for biodiversity management should cooperate with the sectors of health and primary production to seek synergy in preventive actions.

Eradication is difficult and expensive, but possible. Rapid response is crucial.

Because immediate response is more cost-effective and more likely to succeed than action after a species has become established, we recommend an early warning system (EWS) for IAS. Containment action is often needed for a successful eradication program. Such a program must be science-based and have a reasonable chance of success. The involvement of all relevant stakeholders is essential. Public support and acceptance of eradication methods are also important. Monitoring and control after initial efforts are often necessary, and restoration of affected systems is an important consideration.

Containment, suppression, and control are second options, but often have more benefits than costs.

Given the high complexity of the ecological characteristics of both IAS and the habitats and native species they affect, control measures must be developed and applied on the basis of the best current scientific understanding. Specific cost-benefit analyses should be developed and applied for eradication and control programs for IAS.

Selection of control methods must also be based on thorough scientific knowledge. For chemical control the possible problem of negative effects on non-target species and the potential development of resistant types and strains must be carefully addressed. For biological control the possibility of the control agent itself becoming invasive must be avoided. An integrated management approach to IAS involving a combination of mechanical, chemical and biological control measures is often most appropriate. Careful monitoring and co-ordination are needed. Because the cost and benefit factor influences decisions that results in risk analysis that are often very difficult politically, the criteria for such making such decisions should be clearly developed.

Comprehensive international and national action is required.

Numerous global and regional policies are already addressing the problem of IAS. Coordination of implementation and practical co-operation among those responsible for these instruments however, are highly insufficient. Practical prevention, eradication and control measures are also inadequate. We therefore recommend a consolidated action plan. The Convention on Biodiversity (CBD) and the International Plant Protection Convention (IPPC) could take the lead, but trade, transport, travel, and other economic sectors must be closely involved. Other institutions, including the United Nations Environment Programme (UNEP), the World Trade Organisation (WTO), Food and Agriculture Organisation (FAO), and the International Maritime Organisation (IMO) are key components at the international level. These institutions are supported by international non-governmental organisations (NGOs) such as The World Conservation Union (IUCN), World Wildlife Fund (WWF), Wetlands International, Conservation International, and The Nature Conservancy (TNC).

Likewise, at the national level, consolidated and coordinated action is required. This could be part of a national biodiversity strategy and action plan, with close involvement of the economic sectors and identifying people responsible for operative actions involving potential IAS as a key prerequisite. Clear responsibilities for each relevant sector should be identified.

Insurance mechanisms and liability regulations for the spread of IAS are almost non-existent, presenting a major deficiency for controlling the problem. Governments should cooperate with the insurance sector to find solutions, beginning with feasibility studies.

Capacity and expertise to deal with IAS are highly insufficient in many countries. Capacity building and further research on the biology and control of IAS and biosecurity issues should therefore be given attention and priority. This also relates to financial institutions and other organisations responsible for environment and development co-operation, at national and international levels.

A global information system regarding the biology and control of IAS is urgently needed. Tools, mechanisms, best management practices, control techniques and resources should be provided and exchanged. The information system must be linked to the Clearing House Mechanism of the Convention on Biological Diversity.

Awareness raising and education regarding IAS should be given high priority in action plans, and development of economic tools and incentives for prevention are urgently needed.

The scope of GISP

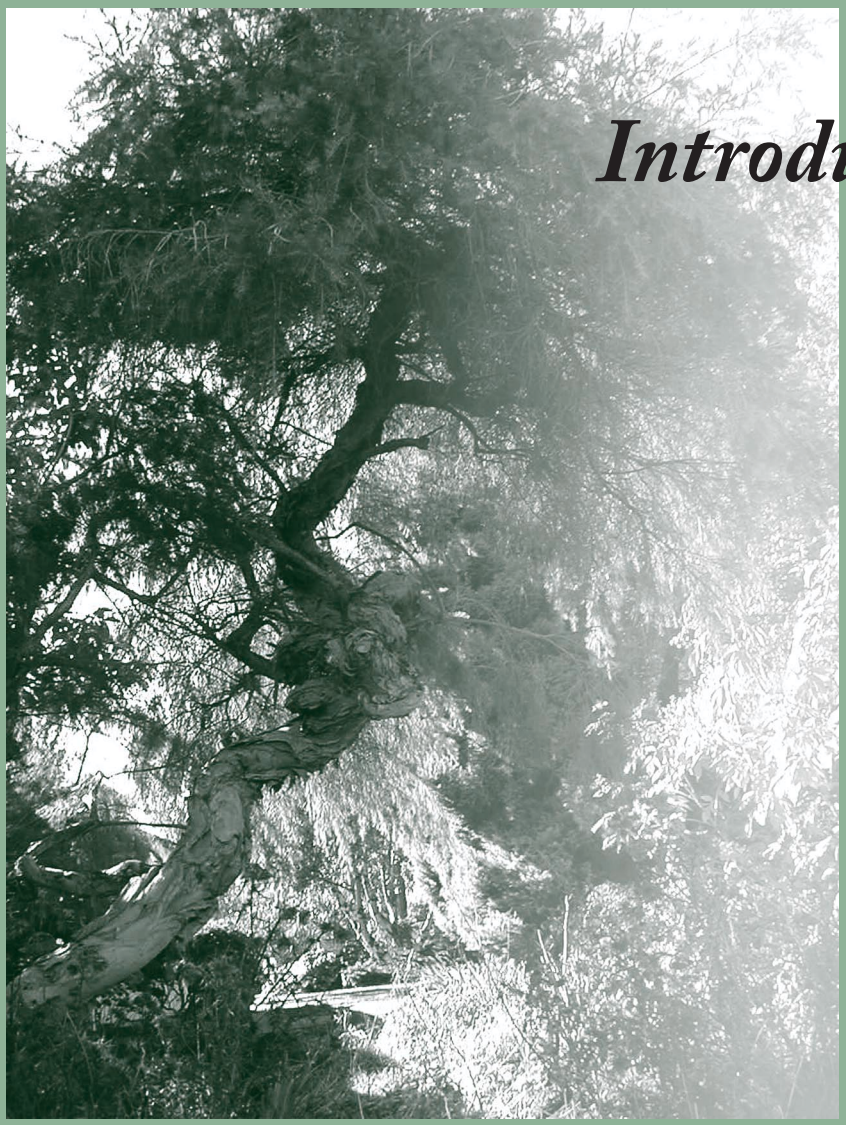
GISP has contributed extensively to the knowledge and awareness of IAS and has developed a guide, "Invasive Alien Species: A Toolkit of Best Prevention and Management" to address the problem. Many challenges, however, still need to be further addressed, and a continuation of the program is recommended. We propose activities to implement five global initiatives:

- Global access to information on invasive alien species threats and their prevention and management.
- Directed action at key pathways of invasive alien species introduction, through public and private sector co-operation.
- Acceleration of critical research and its dissemination.
- Awareness-raising and support to policy development.
- Building cooperation between institutions towards a global biosecurity platform to mitigate the threat of invasive alien species

We also propose regional activities to develop national capacity and regional cooperation in the prevention and management of invasive alien species. This programme proposes to help governments and development agencies to identify and initiate national and regional projects to mitigate threats posed by invasive alien species. It will support existing projects and initiatives and will develop national and international capacity and international networking. This will be achieved through the utilisation and adaptation of the GISP Toolkit of Prevention and Best Management Practices, and other elements developed in Phase I and will use outputs generated by international GISP activities.

Major components of regional and national initiatives will include: national strategy development; surveys, inventory and taxonomic support; pilot projects on invasive alien prevention/management including habitat restoration and raising awareness through public outreach and capacity building programmes.

Chapter 1



Introduction

Introduction

Global trade has enabled modern societies to benefit from the unprecedented movement and establishment of species around the world. Agriculture, forestry, fisheries, the pet trade, the horticultural industry, and many industrial consumers of raw materials today depend on species that are native to distant parts of the world. The lives of people everywhere have been greatly enriched by their access to a greater share of the world's biological diversity. Expanding global trade is providing additional opportunities for societal enrichment. But these movements of species by humans are also having, in some cases, negative impacts on local ecosystems and the species of which they are composed. Local and national economies are also being affected. A new challenge is to identify when these alien or non-indigenous species are bringing about changes that are harmful to ecosystems, biodiversity, health, economics or other aspects of human welfare.

This Global Strategy addresses two rather different aspects of this challenge:

- Species – often vertebrates or plants – that are intention ally moved to new locations to serve social or economic interests, but result in significant negative impacts.
- Species that are transported to new environments inadvertently and have significant negative effects on human welfare.

Those alien species that become established in a new environment, then proliferate and spread in ways that are destructive to human interests are considered "**invasive alien species**" (IAS). For example, a plant or animal transported beyond the ecosystem in which it occurs naturally may multiply out of control, endangering native species in the invaded ecosystem, undermining agriculture, threatening public health, or creating other unwanted and often irreversible disruptions. Seeking to eradicate or control these invasive individuals or populations is not an attack on the species as a whole, which may merit conservation measures in its natural habitat. The objective is to predict which species can cause harm and prevent their introduction, and to effectively deal with the cases in which a species is already causing a problem.

Invasive alien species are now recognised as one of the greatest biological threats to our planet's environmental and economic well being. Most nations are already grappling with complex and costly invasive species problems. Examples include: zebra mussels (*Dreissena polymorpha*) affecting fisheries, mollusc diversity, and electric power generation. In Canada and the USA, water hyacinth (*Eichornia crassipes*) choking African waterways; rats exterminating native birds on Pacific islands; and deadly new disease organisms attacking human, animal, and plant populations in both temperate and tropical countries. Addressing the problem of IAS is urgent because the threat is growing daily, and the economic and environmental impacts are severe.

Numerous international instruments, binding and non-binding, have been developed to deal with certain aspects of the problem of IAS. The most comprehensive is the 1993 Convention on Biological

BOX 1

THE CONVENTION ON BIOLOGICAL DIVERSITY

The Convention on Biological Diversity (CBD) was one of the main results of the UN Conference on Environment and Development, held in Rio de Janeiro in 1992. Entering into force in 1993, the CBD has been ratified by nearly 180 countries. The CBD commits governments to take appropriate measures to conserve biological diversity, ensure the sustainable use of biological resources, and promote the fair and equitable sharing of benefits arising from the utilisation of genetic resources. Under the CBD, governments agree to prepare national biodiversity strategies and action plans; identify genomes, species, and ecosystems crucial for conservation and sustainable use; monitor biodiversity and factors that are affecting biological systems; establish effectively managed systems of protected areas; rehabilitate degraded ecosystems; exchange information, conduct public information programmes; and various other activities for implementing the objectives of the CBD. A CBD secretariat has been established in Montreal. The Subsidiary Body on Scientific Technical and Technological Advice (SBSTTA) of the CBD meets periodically and addresses key issues, including invasive aliens. The CBD has also established an interim financial mechanism, the Global Environment Facility, which provides approximately US$100 million per year to projects for implementing the Convention in developing countries. (http://www.biodiv.org)

Diversity (CBD), which calls on its parties – 178 governments as of 2000 – to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species" (Article 8h). A much older instrument is the 1952 International Plant Protection Convention (IPPC) which applies primarily to plant pests, based on a system of phytosanitary certificates. Regional agreements further strengthen the IPPC (Box 2). The IPPC was extensively revised in 1997 to meet some of the new challenges of plant pests. Other instruments deal with IAS in specific regions (such as Antarctica), sectors (such as fishing in the Danube), or vectors (such as IAS in ballast water). More than 40 instruments or programmes are already in force (Annex 2), and many more are awaiting finalisation and ratification (Shine et al., 2000)

BOX 2

THE INTERNATIONAL PLANT PROTECTION CONVENTION

The IPPC is a multilateral treaty in force since 1952. With 111 governments as Contracting Parties, the purpose of the Convention is "to secure common and effective action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control". Defining pest as "any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products", the implementation of the Convention has applied mainly to crops, but it also extends to the protection of natural flora. Thus the scope of the IPPC covers any invasive alien species that may be considered to be a plant pest. The IPPC Secretariat, housed at FAO in Rome, facilitates the development of internationally agreed upon standards for the application of phytosanitary measures in international trade to prevent and control the spread of plant pests (many of which are invasive alien species). The standards developed under IPPC are recognized by the World Trade Organization under the Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement). (http://www.ippc.int)

BOX 3

THE GLOBAL INVASIVE SPECIES PROGRAMME

The Global Invasive Species Programme (GISP) was initially developed in January 1996 and established in 1997 to address the global threats caused by invasive alien species and to provide support to the implementation of Article 8(h) of the Convention on Biological Diversity. GISP is operated by a consortium of the Scientific Committee on Problems of the Environment (SCOPE), CAB International (CABI), and the World Conservation Union (IUCN), in partnership with the United Nations Environment Programme (UNEP). GISP is a component of DIVERSITAS, an international programme on biodiversity science. GISP seeks to improve the scientific basis for decision making on invasive species; develop capacities to employ early warning and rapid assessment and response systems; enhance the ability to manage invasives; reduce the economic impacts of invasives and control methods; develop better risk assessment methods; and strengthen international agreements. GISP strives to develop public education about invasive species, improve understanding of the ecology of invasives, examine legal and institutional frameworks for controlling invasives, develop new codes of conduct for the movement of species, and design new tools for quantifying the impact of invasives. GISP involves the voluntary contribution from a substantial group of scientists, lawyers, and managers from all parts of the world. (http://www.stanford.jasper.edu/gisp/)

The earlier the problem of an invasive alien species is addressed, the more cost-effective action is likely to be...

The expanding impact of IAS on both global economies and the environment suggests that these international instruments have been insufficient to prevent and combat IAS effectively. Furthermore, expanding international trade is moving ever more organisms more rapidly around the world, thereby increasing the threat of these species to native ecosystems and potentially overwhelming government efforts to prevent unwanted invasions. In response to these concerns, the global scientific community established the Global Invasive Species Programme (GISP) in 1997 (Box 3, Figure 1).

The goal of GISP is to enable governments and other organisations to use the best practices available to control IAS and to promote the development of additional tools and strategies needed to improve global management of IAS. GISP recognises that it is dealing with dynamic ecosystems; it does not advocate attempts to "freeze" any particular ecosystem in an imagined pristine state. Rather, it realises that active management of human effects on ecosystems is required in a time of increasing human impact. This Strategy is one product of Phase I of GISP. It is designed to define the invasive alien species problem, describe its dimensions, discuss its implications, identify those economic sectors that should be involved in action, suggest approaches to management, and recommend appropriate strategies to the responsible agencies.

Because the diverse ecosystems of our planet have become connected through numerous trade routes, the problems caused by invasive alien species are certain to continue. As with maintaining and enhancing

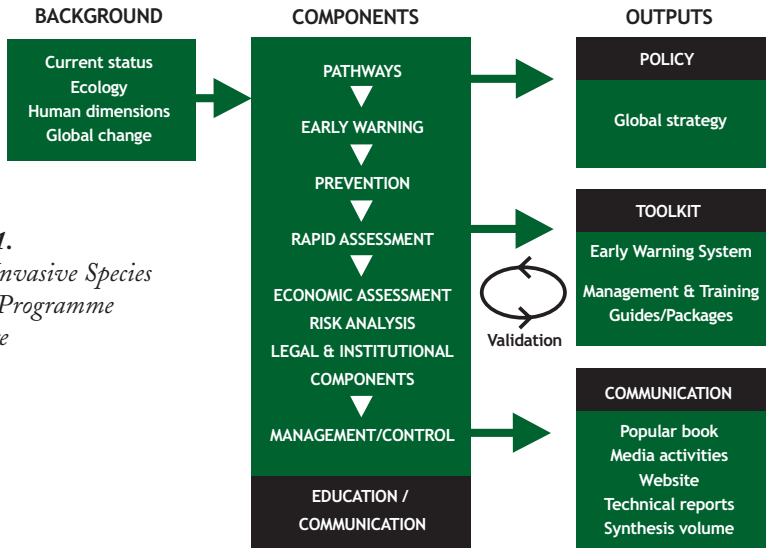


Figure 1.
Global Invasive Species Phase I Programme Structure

health, education, and security, perpetual investments will be required to manage the challenge of IAS. Ideally the solution for dealing with IAS would ensure that:

- An effective system is in place within each nation to prevent the import of unwanted alien species, and appropriate controls exist to prevent the export of native species that might pose a threat elsewhere;
- Each nation has an effective technical communication network, an accessible knowledge base, a planned system for review of proposed introductions, and an informed public;
- Each nation has an effective system of public education and information on invasive alien species.
- Effective research programmes on IAS have been established at local, national, and global levels, including knowledge of the taxonomy of each nation's biota, research on invasion pathways, and research on manage ment measures; and each nation has an effective legal basis for dealing with invasive alien species.

This Strategy will suggest ways of working toward these goals.

BOX 4

THE INTERNATIONAL MARITIME ORGANIZATION

The International Maritime Organization (IMO) has been working on ways to prevent the spread of marine alien organisms in ballast water and sediments since the mid-1970s. In 1997, the IMO Assembly adopted Guidelines for the Control and Management of Ships' Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens. The Guidelines are intended to assist Governments and appropriate authorities, ship masters, operators and owners, and port authorities, as well as other interested parties, in minimizing the risk of introducing harmful aquatic organisms and pathogens from ships' ballast water and associated sediments while protecting ships' safety. They recognize that several States have unilaterally adopted binding regulations to minimize such risks through ships entering their ports, but call for this issue of worldwide concern to be addressed through action based on globally applicable regulations, together with guidelines for their effective implementation and uniform interpretation. Parties have requested the International Maritime Organization's Marine Environment Protection Committee to work towards completion of legally binding provisions on ballast water management, either as an Annex to International Convention on the Prevention on Pollution from Ships, or as a completely new instrument. Negotiations are continuing on the development of a legally binding instrument. (http://www.imo.org)

Why the problem of invasive alien species requires an urgent response

Why the problem of invasive alien species requires an urgent response

The scope of biological invasions is global and the cost is enormous, in both environmental and economic terms. Invasive alien species have invaded and affected native biota in virtually every ecosystem type on Earth. These species have contributed to many hundreds of extinctions, especially under island conditions, whether it be on actual islands, or ecological islands, such as freshwater ecosystems. The environmental cost is the irretrievable loss of native species and ecosystems.

2.1 The impacts of invasive alien species

Invasive alien species occur in all major taxonomic groups. They include viruses, fungi, algae, mosses, ferns, higher plants, invertebrates, fish, amphibians, reptiles, birds and mammals. Within each taxa, numerous species, including perhaps as many as 10% of the world's 300,000 vascular plants, have the potential to invade other ecosystems and affect native biota in a direct or indirect way (Rejmánek et al., 2000).

Invasive alien species can transform the structure and species composition of ecosystems by repressing or excluding native species, either directly by out-competing them for resources or indirectly by changing the way nutrients are cycled through the system. IAS can affect entire systems; for example, when invasive insects threaten native species of insects, they can also have cascading effects on insect-eating birds and on plants that rely on insects for pollination or seed dispersal.

Increasing global domination by a relatively few invasive species threatens to create a relatively homogeneous world rather than one characterised by great biological diversity and local distinctiveness.

No criteria have yet been agreed upon for the minimum damage, spread or size of population needed for an alien species to be considered invasive. However, it is clear that a very small number of individuals, representing a small fraction of the genetic variation of the species in its native range, can be enough to generate, through its reproduction and spread, massive environmental damage in a new environment (Mack, 2000).

Invasive alien species have many negative impacts on human economic interests. Weeds reduce crop yields, increase control costs, and decrease water supply by degrading water catchment areas and freshwater ecosystems. Tourists unwittingly introduce alien plants into national parks, where they degrade protected ecosystems and drive up management costs. Pests and pathogens of crops, livestock and trees destroy plants outright, or reduce yields and increase pest control costs. The discharge of ballast water introduces harmful aquatic organisms, including diseases, bacteria and viruses, to both marine and freshwater ecosystems, thereby degrading commercially important fisheries. And recently spread disease organisms continue to kill or disable millions of people each year, with profound social and economic implications. GISP has not sought to estimate an aggregated economic cost of invasions globally, but one study for the USA estimates costs of $137 billion per year from an array of invasive species (Pimentel et al., 2000).

Agriculture Australia

The Varroa mite, a threat to the Bee keeping industry.

Considerable uncertainty remains about the total economic costs of invasions; however, estimates of the economic impacts on particular sectors indicate the seriousness of the problem. The varroa mite, a serious pest in honeybee hives, has recently invaded New Zealand and is expected to have an economic cost of US$267-602 million, forcing beekeepers to alter the way they manage hives. Beekeepers argue that had border rules been followed or had surveillance detected the mite earlier, the problem could have been avoided entirely. It now appears too late to eradicate the mite, requiring a mitigation plan that is expected to cost $1.3 million in its first stage.

A 1992 report by the Weed Science Society of America estimated that the total cost of invasive weeds was between $4.5 billion and $6.3 billion. While the range of these figures indicates their uncertainty, they also indicate the order of magnitude of impact and argue for significant investments to prevent the spread and proliferation of these species. Other examples are listed in Box 5.

In addition to the direct costs of management of invasives (see Chapter 5), the economic costs also include their indirect environmental consequences and other non-market values. For example, invasives may cause changes in ecological services by disturbing the operation of the

hydrological cycle, including flood control and water supply, waste assimilation, recycling of nutrients, conservation and regeneration of soils, pollination of crops, and seed dispersal.

BOX 5

INDICATIVE COSTS OF SOME INVASIVE ALIEN SPECIES (COSTS IN US$)

SPECIES	ECONOMIC VARIABLE	ECONOMIC IMPACT	REFERENCE
Introduced disease organisms	Annual cost to human, plant, animal health in USA	$41 billion per year	Daszak et al., 2000
A sample of alien species of plants and animals	Economic costs of damage in USA	$137 billion per year	Pimentel et al., 2000
Salt Cedar	Value of ecosystem services l ost in western USA	$7-16 billion over 55 years	Zavaleta, 2000
Knapweed and Leafy spurge	Impact on economy in three US states	$40.5 million per year direct costs $89 million indirect	Bangsund, 1999; Hirsch and Leitch, 1996
Zebra mussel	Damages to US and European industrial plants	Cumulative costs 1988-2000 =$750 million to 1 billion	National Aquatic Nuisances Species Clearinghouse, 2000
Most serious invasive alien plant species	Costs 1983-92 of herbicide control in Britain	344 million/year for 12 species	Williamson, 1998
Six weed species	Costs in Australia agroecosystems	$105 million/year	CSIRO, 1997 cited in Watkinson, Freckleton and Dowling 2000
Pinus, *Hakeas*, and *Acacia*	Costs on South African Floral Kingdom to restore to pristine state	$2 billion	Turpie and Heydenrych, 2000
Water hyacinth	Costs in 7 African countries	$20-50 million/year	Joffe-Cooke, cited in Kasulo, 2000
Rabbits	Costs in Australia	$373 million/year (agricultural losses)	Wilson, 1995 cited in White and Newton-Cross, 2000
Varroa mite	Economic cost to beekeeping in New Zealand	$267-602 million	Wittenberg et al,, 2001

CSIRO Australia

In Australia, rabbits have had extensive impacts on ecosystems, livestock and wildlife.

Such services have both current use value and option value (the potential value of such services in the future). In the South African Cape Floral Kingdom, the establishment of invasive tree species has decreased water supplies for nearby communities, increased fire hazards, and threatens native biodiversity justifying government expenditures of US$40 million per year for manual and chemical control.

Although the loss of crops due to weeds or other alien pests may be reflected in the market prices of agricultural commodities, such costs are seldom paid by the source of the introductions. Rather, these costs are negative "externalities", i.e., costs that an activity unintentionally imposes on another activity, without the latter being able to extract compensation for the damage received. One special feature of biological invasions, as externalities, is that the costs of invasions are largely self-perpetuating, once they are set in motion. Even if introduction ceases, damage from the invasives already established continues and may increase.

CABI Bioscience

Mice infest agricultural stores, spread disease and threaten indigenous rodents.

Most evidence of economic impact of IAS comes from the developed world. However, there are strong indications that the developing world is experiencing similar, if not proportionally greater, losses. Invasive alien insect pests, such as the white cassava mealybug and larger grain borer in Africa pose direct threats to food security. Invasive weeds constrain efforts to restore degraded land, regenerate forests and improve utilisation of water for irrigation and fisheries. Water hyacinth and other alien water weeds affecting water use currently cost developing countries over US$100 million annually. Alien invasive species pose a threat to the success of over 13 billion dollars dedicated to

current and planned World Bank funding to projects. The projects at risk are related to the irrigation, drainage, water supply, sanitation and power sectors (Joffe and Cooke, 1998).

Further, many introductions are unintentional, including most invertebrates and pathogens. Prices or markets cannot readily reflect the costs of these introductions. But even in the case of introductions involving deliberate imports to support agriculture, horticulture, forestry, and fisheries, market prices for seeds, plants, or foods, do not generally reflect the environmental risks associated with their use. Thus producers have little financial incentive to take account of the potential cost of the loss of native species or disturbance to ecosystem functions. The policies developed to deal with conventional externalities involved in the general problem of biodiversity loss – such economic tools as taxes, subsidies, permits, and so forth – may not always be well suited to deal with the problem caused by invasions. This point highlights the urgent need for new economic approaches to deal with IAS.

G. Ruiz Smithsonian

Testing of ballast water for potentially harmful organisms is vital to understanding this important pathway.

2.2 Global trade and invasive alien species

The increased mobility of people and their goods bring an increased likelihood of movement of species around the planet, either deliberately in the form of commodities such as livestock, pets, nursery stock, and produce from agriculture and forestry. Further introductions occur inadvertently as species are transported in packaging, ballast water, and on the commodities themselves. Globalisation of the economy is demonstrated by the increase in the value of total imports from US$192 billion in 1965 to US$5.4 trillion in 1998, a 28-fold increase in just over 30 years (World Resources Institute, 1994; World Bank, 2000). Imports of agricultural products and industrial raw materials increased from US$55 billion in 1965 to $482 billion in 1990; these have the greatest potential to contribute to the problem of IAS because unwanted species, especially insects and other invertebrates, may be physically transferred with the traded commodity. A significant amount of global trade is seaborne, and marine organisms are being transported around the world by ships. These organisms occur in the ballast tanks and on hulls of vessels (Ruiz et al., 1997, 2000). Ballast water is a particularly important vector of IAS in coastal waters as ships take on large quantities of ballast water in one port and discharge it in another part of the world, transferring a broad diversity of waterborne organisms in the process (Carlton, 1989; Carlton and Geller, 1993; Smith et al., 1999; Ruiz et al., 2000).

1890

Sailing ships at dockside; soil heaps in the foreground are the dry ballast used in early shipping of goods, functioning as depositories for seeds and other organisms.

International trade in goods and services between the current 139 Members of the World Trade Organisation (WTO) is guided by the 1994 Uruguay Round Agreements. This regime provides for binding rules, enforced by a compulsory dispute settlement mechanism, designed to ensure that governments extend free market access to each other's products and services. Particularly relevant to alien species that are characterised as pests or diseases is the 1995 WTO Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement) as noted in Box 6, which allows Members to adopt national measures or standards to: (1) protect human, animal and plant life from the risks arising from the entry, establishment or spread of pests, diseases, or disease-carrying organisms; and (2) prevent or limit other damage within the territory of the Member from the entry, establishment or spread of pests (Box 6).

Some governments are reported to be putting increasing pressure on their national quarantine agencies to adopt "acceptable" rather than minimum risks of introduction of invasive species as a means of stimulating trade.

BOX 6

WTO AGREEMENT ON SANITARY AND PHYTOSANITARY MEASURES

The SPS Agreement under the WTO (http://www.wto.org) is designed primarily to ensure that import restrictions are not used as a disguised form of commercial protectionism. It is not a mechanism to ensure that governments have adequate standards in place. However, the import restrictions must be based on scientific evidence, and applied only to the extent necessary to protect human, animal or plant life or health. The burden of proof remains with the recipient country. The Agreement seeks to protect countries from various pest species while promoting the principles of free and fair trade and makes provision for safe trade by promoting or requiring the use of:

- international standards as a basis for SPS measures;
- risk assessment based on scientific principles and evidence;
- consistency in the application of appropriate levels of protection;
- least trade restrictive alternatives;
- acceptance of equivalent measures;
- transparency through notification of trade measures.

This policy change may accelerate the spread of alien species, especially as East-West trade within and between hemispheres becomes increasingly common. The growth of global economic activity will result in greater impacts because the spread of potentially invasive species will accelerate as the trade in biological products expands.

The globalisation of trade and the power of the Internet offer new challenges to those seeking to control the spread of IAS, as sales of seeds and other organisms over the Internet pose serious new risks to the biosecurity of all nations. Controls on both import and export of species are required as part of a more responsible attitude of governments toward the potential spreading of invasive species around the world. While receiving countries must ensure that they are able to control the imported species, few countries yet have effective controls in place. Because global trade has such a profound influence by moving species around the world, it is particularly important to ensure that concerns about IAS are built into relevant trade negotiations. Initial efforts are being made in this regard. For example, the Biosafety Protocol under the CBD is part of the global trade regime; it is to be mutually supportive of any agreements under the World Trade Organisation (WTO). This Protocol is based on the principle that potentially dangerous activities can be restricted or prohibited even before they can be scientifically proven to cause serious damage, whereas decisions under trade law typically require "sufficient scientific evidence" to lead to such restrictions. In any case, IAS are so important that they should form part of the WTO agenda.

2.3 Human health and invasive alien species

The dynamism among invasive pathogens, human behaviour, and economic development are complex and depend on interactions between the virulence of the disease, infected and susceptible populations, the pattern of human settlements, and their level of development. Large development projects, such as dams, irrigation schemes, land reclamation, road construction and population resettlement programmes, have contributed to the invasion of diseases such as malaria, dengue, schistosomiasis and trypanosomiasis. The clearing of forests in tropical regions to extend agricultural land has opened up new possibilities for wider transmission of viruses that carry haemorrhagic fevers that previously circulated benignly in wild animal hosts. Examples include Argentine haemorrhage fever, "Guaranito" virus, Machupo virus, and Basia virus. Some pathways for the biotic invasion are complicated. For example, the prevalence of lymphatic filariasis in the southern Nile Delta has increased 20-fold since the building of the Aswan dam in the 1960s. This increase has been due primarily to the increase in breeding sites for the mosquito vector of the disease following the rise in the water table caused by the extension of irrigation. The problem has been exacerbated by increased pesticide resistance in the mosquitoes, due to heavy agricultural pesticide use and by rural-to-urban commuting among farm workers. Thus invasive species combined with variations in inter-annual rainfall, temperature, human population density, population mobility and pesticide use all contribute to one of the most profound challenges of invasive species: the threat to human health.

GISP Archive

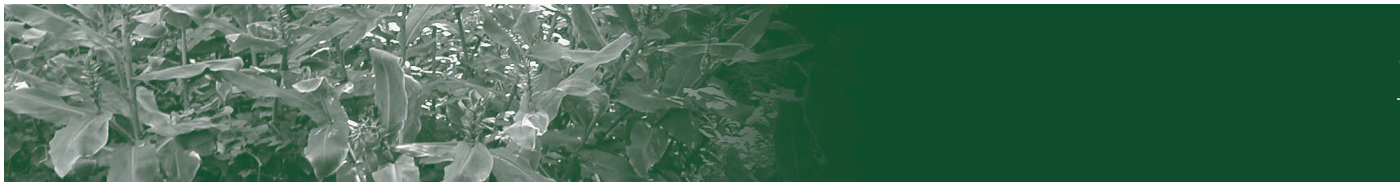
The imported red fire ant from South America impacts native species and livestock. Allergic reactions to the stings can be fatal to people.

Every alien species needs to be considered potentially invasive, until convincing evidence indicates that it presents no such threat.

Infectious disease agents often, and perhaps typically, are invasive alien species (Delfino and Simmons, 2000).

Unfamiliar types of infectious agents, either acquired by humans from domesticated or other animals, or imported inadvertently by travellers, can have devastating impacts on human populations. Pests and pathogens can also undermine local food and livestock production, thereby causing hunger and famine. Examples include:

- The bubonic plague spread from central Asia through North Africa, Europe, and China using a flea vector on an invasive species of rat.
- The viruses carrying smallpox and measles spread from Europe into the Western Hemisphere shortly following European colonisation. The low resistance of the indigenous peoples to these parasites helped bring down the mighty Aztec and Inca empires.
- Rinderpest, a viral disease, was introduced into Africa in the 1890s via infected cattle, subsequently spreading into both domesticated and wild herds of bovids throughout the savannah regions of Africa, changing the mammalian composition of much of the continent; up to 25% of the cattle-dependent pastoralists may have starved to death in the early 20th century because rinderpest wiped out their cattle populations.
- The influenza virus has its origins in birds but multiplies through domestic pigs which can be infected by multiple strains of avian influenza virus and then act as genetic "mixing vessels" that yield new recombinant-DNA viral



strains. These strains can then infect the pig-tending humans, who then infect other humans, especially through rapid air transport.

Indirect health affects associated with IAS include the use of broad spectrum pesticides against invasive pests and weeds. Free from their natural controlling factors, these organisms often reach sustained outbreak levels that encourage widespread and chronic pesticide use.

Invasive pathogens are of particular concern to human health relative to rapid environmental changes and ecological disturbances. As a result, the type, scale and tempo of change in health risk is accelerating under the contemporary conditions of global change.

2.4 Climate change and invasive alien species

The scientific community now generally accepts that global climate change is a reality, and that many biological impacts can be expected. These impacts may include alterations in species distributions and changes in species abundance within existing distributions, resulting from direct physiological impacts on individual species, changes in abiotic factors, changed opportunities for reproduction and recruitment and altered interactions among species (Karieva et al., 1993; Sutherst, 2000). Changes in climate may also produce more conducive conditions for the establishment and spread of invasive species, as well as change the suitability of local climates for native species and the nature of interactions among native communities.

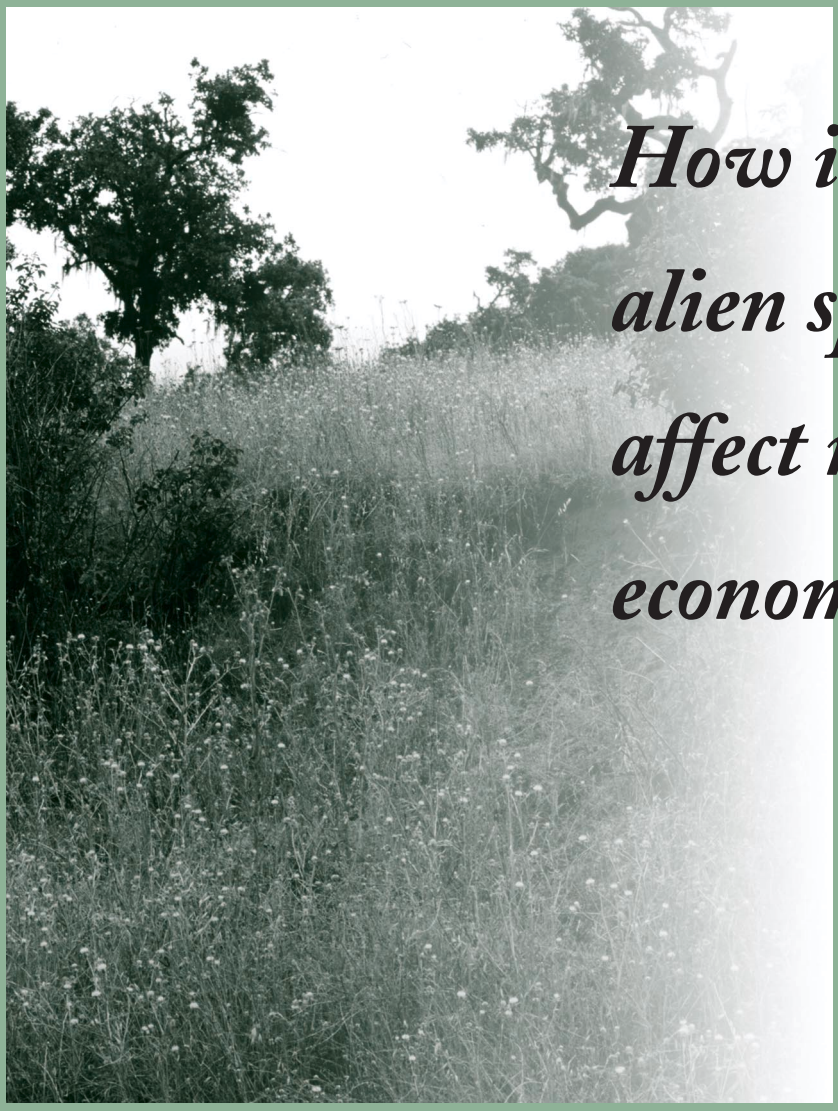
Climatic and landscape features set the ultimate limits to the geographical distribution of species and determine the seasonal conditions for growth and survival. As climate changes, patterns of production and trade in agricultural commodities will change as well, with crops adapted to tropical conditions being grown more competitively in higher latitudes and altitudes. The opportunities for tropical IAS to contaminate such crops in new ranges will also increase.

Climatically induced stress on plants can reduce their ability to resist invaders. Plants stressed by a changing climate may be more prone to insect or pathogen damage, lowering their competitive capacity (though insect or pathogen vulnerability has nothing necessarily to do with competition). The greatest impacts of climate change on invasive species may arise from changes in the frequency and intensity of extreme climatic events that disturb ecosystems, making them vulnerable to invasions, thus providing exceptional opportunities for dispersal and growth of invasive species. (Mooney et al.; 2000). For example, a drought that kills native plants can leave gaps in vegetation that may be quickly occupied by IAS. Both droughts and freezing are likely to change in frequency and intensity under climate change, reducing the resistance of trees to insect attack. And by altering the frequency, intensity and duration of flooding, climate change will affect the incidence of episodic recruitment events of invasive species, enabling aggressive species to escape from local, constrained refuges. For example, the "sensitive plant" (*Mimosa pigra*), a woody legume, escaped from the Darwin Botanical Gardens during a major flood that took seed into the Adelaide river, which transverses the sensitive Kakadu National Park, in Australia. *M.pigra* has now become a significant problem in the region and in other areas of the world.

GISP concludes that because of the potential for economic and ecological damage when an alien species becomes invasive, every alien species needs to be treated for management purposes as if it is potentially invasive, unless and until convincing evidence indicates that it is harmless in the new range. This view calls for urgent action by a wide range of governmental, intergovernmental, private sector, and civil institutions.

M. Rejmanek

The originally treeless highlands of Santa Cruz island, Galapagos will likely become entirely covered with Cinchona pubescens at the current rate of spread. Affecting ground nesting birds and displacing native vegetation it is altering the delicate balance of the islands.



How invasive alien species affect major economic sectors

How invasive alien species affect major economic sectors

The problem of IAS is not simply the concern of ecologists or conservation biologists. This chapter indicates some of the major economic sectors that are, or should be, concerned about these organisms, suggesting that new partnerships with these sectors could lead to progress on this issue. These short sections only highlight a few of the issues that are important for the respective sectors.

3.1 Tourism and invasive alien species

Tourism – a form of trade where people travel to the resource instead of vice versa – can facilitate the spread of invasive species. With some 650 million people crossing international borders as tourists every year, the opportunities for them to serve as vectors for IAS is profound and increasing. Human travelers can intentionally carry living plants that eventually become invasive. They can return home with fruits and other living or preserved plant materials that carry with them potentially invasive insects that can have profound influences on agriculture. They can also carry parasites and diseases between countries.

While much of the responsibility for addressing tourism-related issues of IAS will rest with the customs and quarantine offices in the destination countries, tourism-related agencies (both public and private) need to become more aware of the role that tourists play as vectors of IAS. Promoting awareness and taking measures to educate travel guides, consultants and staff. Ultimately generating awareness for tourists on the hazards of the spread of such species.

3.2 Agriculture and invasive alien species

The domestication of plants and animals that began 10,000 years ago has involved the intentional and beneficial movement of many species around the world. Most regions depend today on alien crops and livestock, and indeed the greatest levels of agricultural production for any crop are usually outside its region of origin. This global movement of domesticated species has been accompanied by a growing invasive alien species problem. Unintentional introduction of pests and diseases of agriculture as contaminants in crops and animals has led to particularly severe problems, because alien species thrive in new ecosystems where their hosts are abundant and their own natural controlling factors may be absent. In the USA, approximately 15% of IAS cause severe damage; documented losses caused by 43 invasive alien insects for the period 1906 to 1991 has been estimated at over US $ 92.5 billion (U.S. Congress, Office of Technology Assessment, 1993). Recent increase in South-South and North-South horticultural trade has greatly increased the movement of IAS into forests, including pests such as whiteflies, leaf miners and thrips.

Many of the invasive weeds affecting agriculture and natural grasslands have been spread around the world as contaminants in crop seed. Farmers from Eastern Europe took such weeds as leafy spurge (*Euphorbia esula*), knapweed (*Centaurea spp*), purple loosestrife (*Lythrum salicaria*) and sow thistle to the United States. Today, international development programmes continue to move weed seeds inadvertently with improved crop varieties for testing in developing countries.

Emergency food aid is also a pathway of agricultural invasives – the neotropical weed *Parthenium hysterophorum* recently arrived in Africa through grain shipments for famine relief to Ethiopia, where it has earned a local indigenous name which translates to "no crop"

Agricultural trade has also created IAS problems for natural ecosystems. In some cases this involves contaminants in agricultural produce. In other cases, however, the alien crops or livestock have proven invasive themselves. Rabbits, deer and fur-bearing mammals have either escaped domestication or were intentionally released to have major impacts on native fauna and ecosystems.

CABI Bioscience

Indian farmers spend endless hours clearing fields to eradicate Mikania, also known as "mile a minute" vine.

Agriculture presented vast new opportunities for some species to benefit from human modifications of natural habitats. Indeed, the problem of invasive species arguably became significant only with the advent of agriculture. Farmers everywhere are plagued by invasive weeds, plant pests, and pathogens. These agricultural problems generate a massive response by many agencies.

However, many existing markets are prevented from operating efficiently in regards to IAS by agricultural policies and institutions. For example, fiscal policies have promoted management regimes that have increased the susceptibility

of agroecosystems to invasions, and subsidies designed to promote cash crops as a means of increasing export revenue have encouraged the use of farm inputs that may open agroecosystems to biotic invasions (Perrings, Williamson, and Dalmazzone, 2000). In developing countries, farm incomes may be so low that farmers are unable to cope with potentially invasive species.

Many farmers are increasingly concerned about crops which are genetically modified organisms (GMOs), organisms in which the genetic material has been altered in a way that does not occur naturally by mating or recombination, thereby introducing genes from distantly-related organisms. GMOs are "alien" because they have no normal distribution and occur nowhere in the natural environment until released. As with alien species that become invasive, it is possible that the release or escape of transgenic, recombinant or novel DNA in agriculture might have severe and irreversible effects on environmental safety. For these reasons, a regulatory framework to control the testing, movement and release of GMOs may have many points of similarity with measures to regulate introductions of alien species. A few countries, notably New Zealand, regulate GMOs under the same legislation used to address alien species introductions.

3.3 Forestry and invasive alien species

Alien trees have long been introduced for commercial forestry, agroforesty, erosion control or landscaping. Over time and with increasing dissemination, the invasive potential of woody species such as pines, eucalypts and multipurpose tree legumes is becoming apparent. Salt cedar (*Tamarix* spp) was introduced from central Asia to the south-west United States nearly 200 years ago, partly to control erosion along river banks. The tree now forms dense thickets on more than 400,000 ha of riparian habitat, but these thickets have little value for most native animals, and are having severe impacts on hydrological systems. Invasive alien pines and acacias in South Africa threaten not only unique native flora but reduce water tables. The national Working for Water Programme addresses these invasive problems by engaging tens of thousands of people in rural communities to clear these weeds from water catchment areas and provides resources to the communities with this effort (Working for Water Programme, 1999/2000). Many countries are experiencing great problems with alien *Eucalypts* from Australia. The various species of *Eucalyptus* can be particularly harmful in environmental terms because their leaf litter contains chemical compounds that prevent other species from growing.

Forest production can be seriously affected by pests and diseases. Commercial forestry has traditionally combated alien pest problems on alien tree species by simply felling trees and growing another, unaffected tree species, but this is no longer economical in many circumstances, and methods like eradication and biological control are increasingly employed. The recent opening of trade in forest products across the Pacific between China and the former Soviet Union and North America has led to a dramatic increase in pest and disease problems on both sides through accidental exchange of pest and disease faunas which had previously been isolated. Particular problems occur when alien pests and diseases affect native forest species. Alien diseases and pests have cause major changes in the composition of forests in eastern North America over the past century, including the decline of species like elm, chestnut and hemlock. Recently, the brown spruce longhorn beetle (*Tetropium fuscum*) arrived in Nova Scotia from Europe in packing wood and has become established on spruce trees in the 75 ha Point Pleasant Park. While the beetle in its European natural habitat feeds primarily on dead wood, it is infesting healthy trees in the park, and it poses a serious threat to North American forests. The government of Nova Scotia is so concerned about the threat to its US$1.5 billion per year softwood industry that it will cut down and incinerate the 10,000 affected trees, in hopes of eradicating the beetle before it can spread (Motluk, 2000). A dramatic example of the latter is the recent invasion of eastern Canada by the brown spruce longhorn beetle that apparently arrived in Halifax from Europe in packing wood. It has become established in the 75 hectare Point Pleasant Park, where it has infested red spruce trees, burrowing too deeply to be reached by pesticides. While the beetle in its European natural habitat feeds primarily on dead wood, it is infesting healthy trees in the park, and it poses a serious threat to North American forests. Red spruce is the most economically important tree in maritime Canada, but the beetle appears also to attack white and black spruce. (Wittenberg et al., 2000)

Careful management can minimise the danger of alien trees escaping cultivation to become invasive in natural ecosystems. Forestry agencies, both public and private, therefore need to be aware of the danger of the unintentional entry of IAS, conduct detailed risk assessments before intentionally introducing exotic trees, and ensure that any such species do not become invasive. Careful planning of forestry operations using alien conifers, *Eucalyptus*, or *Acacia* can reduce the probability of their escaping and becoming invasive. The use of native species or sterile trees that can only be established through cuttings is the only sure way to prevent alien trees from becoming invasive.

3.4 Fisheries and invasive alien species

Fish are introduced for commercial or sport fishing or for contained use in aquaculture and mariculture facilities. Without proper management procedures and containment facilities, the risk of escape and/or spread may be particularly high in aquatic environments. The Atlantic salmon disappeared from many rivers in Norway after the introduction of the Baltic salmon for aquaculture, possibly because of an alien parasite carried by the Baltic salmon. In South Africa, 41 species of alien fish had become naturalised by 1988 after being introduced for aquaculture, sport

angling, and biological control (mosquitoes, algae) or deliberately translocated to stock artificial lakes and reinforce populations of rare species (de Moor and Bruton, 1988). In England, amphibious alien crayfish escaped from fishmongers' stalls and established themselves in London's channels and ponds (de Klemm, 1996). In response to such threats, Parties to the CBD have called for particular attention to IAS in coastal and marine habitats.

Lens Bursell

The Nile perch (Lates nilotica) introduced to Lake Victoria in 1954 has resulted in the extinction of over 200 endemic species of fish. The harvest for firewood needed to process the fish has led to the erosion of soils and the sediment runoff dramatically impacts water quality. The local economy has had negative impacts as a result.

As with forestry, fisheries have been profoundly affected by IAS. For example, the introduction of Nile perch into African Rift Valley lakes has increased profits from commercial fishing and contributed to foreign exchange gains, at the expense of the extinction of numerous endemic fish species (especially in Lake Victoria). And in China's Dianchi Lake, more than 30 alien species of fish were found in the 1970s, reducing the number of native species from 25 to just 8 over a period of 20 years (Xie, 1999).

Another example of a purposeful introduction gone wrong is the extensive stocking programme that introduced African tilapia (*Oreochromis* spp) into Lake Nicaragua in the 1980s. The tilapia found Lake Nicaragua to be a congenial habitat; the fish were able to grow rapidly, feed on a wide range of plants, fish and other organisms, and form large schools that can migrate long distances. Further, they are maternal mouth brooders, so a single female can colonize a new environment by carrying her young in her mouth. They are also larger than the native species and replace them in territorial conflicts. Even worse, these fish have also proven adaptable to salt water habitats, and may invade Nicaragua's coastal zone as well, adversely affecting otherwise productive marine fisheries and valuable estuarine nursery grounds. The alteration of Lake Nicaragua's ecosystem by the explosive growth of tilapia populations is likely to have effects on the planktonic community and primary productivity of the entire lake, destroying native fish populations and perhaps leading to unanticipated con-sequences (McKay et al., 1995).

3.5 Horticulture and invasive alien species

Introductions of plants for ornamental purposes are reinforced by consumer demand for novelty and complicated by low levels of understanding of the risks of biotic invasion. In the past, European colonisers often established acclimatisation societies to introduce familiar plants. More than 70% New Zealand's invasive weeds were intentionally introduced as ornamental plants. In the Auckland region, more than 615 introduced plant species are known to have become established and four new species become established there each year. Growing economies expand consumer demand for imported ornamental plants with little regard to the possibility that these species may become invasive. Responsibility under such conditions is unclear.

Those involved in fisheries need to consider carefully the potential negative impacts that may follow from introduction of alien species of fish, many of which may become invasive.

3.6 Conclusions

This chapter indicates a few of the many economic sectors that are significantly affected by invasive alien species. This list could be greatly extended, but it already indicates that IAS are of broad social and economic relevance. Clearly, any comprehensive programme to address IAS problems will need to involve at least the economic sectors identified in this chapter.

Combinations of events can complicate the invasive species problem. For example, any increase in the frequency and intensity of extreme climatic events associated with the intensification of the hydrological cycle under global climate change has great potential to disrupt the fragile balance of food supplies and refugee problems in regions already made vulnerable by over-population and land degradation. Thus the impacts of droughts, made more severe by political unrest and over-exploitation of natural resources, can lead to increasing movements of refugees accompanied by livestock. These agents can inadvertently carry exotic parasites with them. The associated food and other materials, such as seeds, that are provided as drought relief could also act as vectors for invasive species or even include invasive species. Such risks are perhaps greatest in Africa, which is particularly prone to drought and where political boundaries often are poorly supervised. These factors suggest that emergency responses to legitimate humanitarian concerns such as famine can carry long-term implications for native ecosystems, including agro-ecosystems, through the introduction of IAS.

Our hope is that this Strategy will be a significant step in achieving better coordination among these economic sectors in addressing the problem of invasive alien species. Such co-ordination will need to be based on the best available understanding of the biology of invasions and the management responses available.

Chapter 4

The movement of species

The movement of species

Species invasions have three main elements. First, the source population is found where the species naturally forms part of the native ecosystem (though other invaded ecosystems often are a secondary source). Second, pathways are the routes by which species move from one locale to another, either within a country or between countries. And third, destinations are locales where the new species arrives, either intentionally or inadvertently. Fourth, vectors are the means by which species from a source population follows a pathway to a new destination.

4.1 Sources

Species that are potential invaders are usually not a problem where they are native species interacting with competitors. Because the problem is not perceived to be "theirs", few governments provide significant investments to prevent export of potential IAS, except perhaps for "domestic aliens" that are moved by people to new habitats within large nations, or between islands in island nations.

Sources of IAS are of particular concern when considering pest species of agriculture and forestry because products are often being accepted on the international market only if they come from a pest-free area. Under the World Trade Organization (WTO) the source location of a potential invasive species has led to the concept of "area freedom", which states that a commodity may be exported only if it can be demonstrated that the invasive species is absent from the growing area (pest-free area). For example, the Queensland fruit fly (*Bactrocera tryoni*)is invasive wherever suitable fruits are found in favourable climates. A major citrus growing area in Australia has WTO "area freedom" status for the fruit fly and the status is being maintained by mass releases of sterile fruit flies, which are cost-effective only at low population levels, preceded by insecticidal baits and sprays. But with global climate change, the distribution of these pest-free areas may change and the status of different source areas may become more uncertain.

R. Wittenberg

In New Zealand, more than 60 million brushtail possums infest forests and farms, defoliating trees, raiding orchards and preying on native birds.

Source locations of an IAS may at the same time be a destination for other IAS. Ironically, a species may be an endangered icon in its natural habitat but a dreaded pest in its new range, strictly protected by one set of laws at home while being relentlessly pursued by another set of laws where it is invasive; the brushtailed possum (*Trichosurus vulpecula*), for example, is protected in its native Australia but deemed a pest in New Zealand.

4.2 Pathways

The pathway and the vector that transports the invader are important links in an invasion. If the vector can be intercepted, then the potential invasion can be prevented. Most vectors are human-assisted transport mechanisms that move organisms across their natural barriers. The probability of a species surviving a ship voyage depends partly on the longevity of the organism (though this is now much less of a constraint because ship transport is so rapid). Thus plant seeds may be more likely than some insects to survive transport to distant locations, perhaps mixed with the agricultural commodity being transported; and relatively long-lived beetles that bore into wooden packing materials present different challenges than short-lived fruitflies.

Examples of vectors that transport organisms unintentionally include shipments of food, household goods, wood and wood products, new and used tyres, animal and plant products in various conditions, ballast (whether dry or water), containers, pallets, internal packaging materials, and humans (including their various pathogens and disease agents such as bacteria and viruses).

This diversity of vectors following multiple pathways yields an extraordinarily complex matrix, requiring equally complex management. Operationally, different vectors will have different strengths in different countries, and in different sub-regions within a country. Multiple vectors can operate along the same pathways at the same time; and vectors are constantly changing, with some aspects more predictable than others.

4.3 Destinations

Whether an alien species becomes invasive at its destination depends on what ecological role the species may play, and on additional factors such as:

- the degree to which the immigrant species arrives at a time when it can tolerate the environmental conditions that are being expressed currently;

- its direction and rate of spread;
- population dynamics;
- its interactions with resident organisms in the new range; and
- the type of ecosystem it is invading.

A holistic approach to dealing with IAS is advisable, including identification of sources, pathways, interception, and rapid response at the destination. Action at the source of the potentially invasive organism is best because such action leaves the other options available for species that nonetheless enter a new range.

Whether a species becomes established depends in part on the competition that exists, leading some researchers to emphasize the importance of disturbance in providing temporary windows of opportunity for invasive plant species. Disturbance could also reduce predation and grazing, or create critical microclimates that facilitate establishment. Thus growing human disturbance of habitats around the world improves the likelihood of establishment of weeds; and this likelihood may be increased further with climate change.

Managing the problem of potential invaders requires interventions aimed at one or more of these elements. For example, at the source location, efforts can be made to avoid exports of species likely to become invasives. Pathways and vectors can be addressed through measures such as ensuring that potential IAS are not carried in ballast water or in cargo containers. And measures to intercept and eradicate potentially IAS at the point of introduction are effective in some cases, as with quarantine efforts for some pathogens.

Under GISP Phase I, Richardson et al. (2000) developed the simple conceptualization of the invasion process as shown in Fig. 2 (here adapted to all IAS rather than only plants). Following this scheme, invasion is a process requiring a taxon to overcome various abiotic and biotic barriers. Phases of the process can be defined on the basis of the relevant barrier(s) that are (or are not) overcome. **Introduction** means that the species (or its propagule) has overcome, through human agency, a major geographic barrier (A in Fig. 2). **Establishment** begins when environmental barriers (B) do not prevent individuals from surviving and when various barriers to regular reproduction (C) are overcome; a taxon has become is established after overcoming barriers A, B and C. At this stage populations are sufficiently large that the probability of local extinction due to chance environmental events is low (MacArthur, 1972; Menges, 2000; Mack, 2000).

Spreading of a species into areas away from initial sites of introduction requires that the introduced species also overcome barriers to dispersal within the new region (D) and can cope with the abiotic environment and biota in the general area (E). Many IAS appear to first colonize disturbed habitats and some of these spread into semi-natural communities. The colonization of mature, successional relatively undisturbed communities usually requires that the alien taxon overcomes resistance posed by a different category of factors (barrier F in Fig. 2).

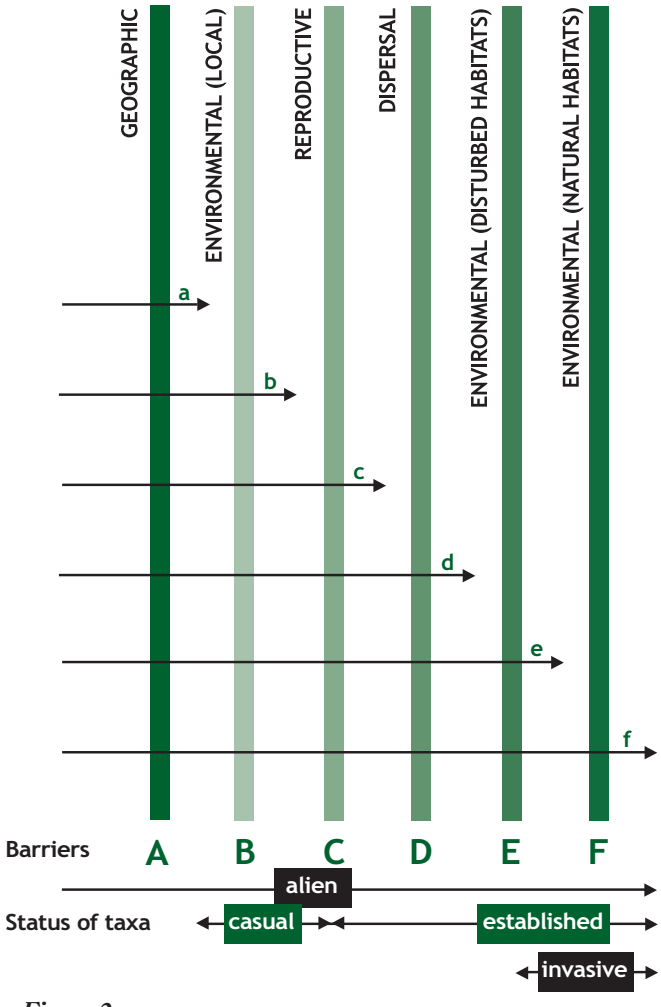


Figure 2.
Invasion process
(adapted from Richardson et al (2000)

4.4 Conclusions

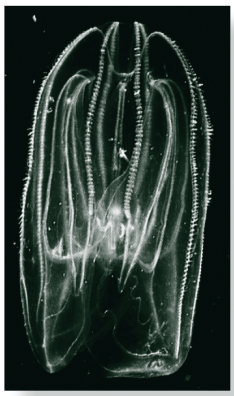
Based on the improved understanding of how species invade, we advocate a holistic approach to dealing with invasive alien species, including attention to sources, pathways, interception, and rapid and thorough response at the destination. Action at the source of the potentially invasive organisms is best, because this leaves the other options available for species that nonetheless enter a new range.

We must expand our consideration of invasion management options to include both species-level and vector-level approaches. Although it is sometimes possible to implement species-specific prevention measures, targeting known IAS, some vectors deliver entire such a broad mix of species that a species-level approach is simply not feasible. For example, ballast water delivers an entire community, potentially including tens to hundreds of species per ship, and the species-level identity of this community is difficult to discern in real-time, allowing for species-level decisions. Thus, it becomes imperative to implement vector management to reduce the risk of IAS invasions in many cases.

Analysis of invasion patterns and vectors is key to both understanding the risk of invasions and steps needed to minimise this risk. Retrospective analyses of invasion patterns identify which species are (or will likely become) IAS as well as the vector strength (i.e., the relative importance of various vectors) in delivery of IAS. Analysis of vector operation will identify and track emergence of new risks, as vectors change in strength, allowing a proactive management response. These analyses should be done on a regional basis, as there are clearly differences among regions (by taxa, vectors, etc.), and would benefit greatly from use of database tools, which could be shared among regions.

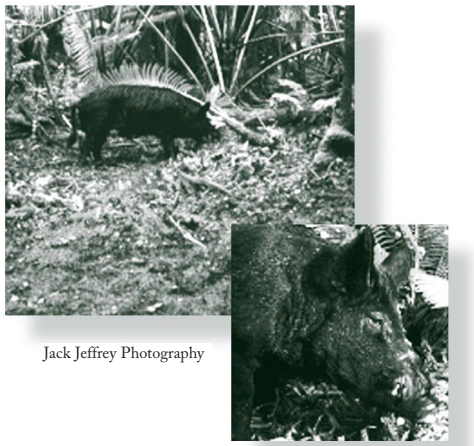
Jack Jeffrey Photography

Avian malaria, spread by the southern house mosquito (Culex quinquefasciatus) also an introduced species, has contributed to the extinction of at least 10 native bird species in the Hawai'ian islands.



Harbison

The Atlantic Comb Jelly (Mnemiopsis leidyi) transported via ballast water from the east coast of USA to the Black Sea causing a very sharp decrease in all life forms, most notably pelagic fish and zooplankton, the result collapsing the fisheries in that region.



Jack Jeffrey Photography

The feral pig (Sus scrofa), a well known example a devastating introduction that has contributed to the spread of disease, demise of native species, altered ecosystem functioning and has been the subject of prevention, eradication and control programmes across the globe. However, the species is important to some native cultural traditions in areas where it has become established.

Jack Jeffrey Photography

The Indian mongoose, a voracious and opportunistic predator, introduced to Fiji, West Indies, Mauritius and Hawai'i to control rats. It has instead, caused the local extinction of several endemic species of birds, reptiles, and amphibians.

Chapter 5

The ecology of invasive alien species

The ecology of invasive alien species

Scientists working on invasive species seek to address several basic questions, such as:

- Which taxa invade?
- How fast do they invade?
- What is the ecological impact of their invasion?
- What types of ecosystems are susceptible to invasive taxa and their impacts?
- How can harmful invaders be prevented, eradicated or controlled?

This chapter will address the first four questions, while the last will be covered in Chapter 6.

5.1 Which taxa invade?

The species composition of an ecosystem at any given location and time depends on current environmental conditions, levels and types of disturbance, balance of extinction and recruitment, and composition of the regional pool of species. Increasing levels of human transformation of ecosystems may accelerate environmental change, and the dramatic increase in the deliberate and inadvertent transport of biota across the globe inevitably will increase the regional species pool, while perhaps also decreasing native species and thereby decreasing the global species pool. This combination of factors sets the stage for a radical alteration of an ecosystem. Species that take advantage of disturbances to colonize often are especially favoured because of increasing disturbance of mature ecosystems by people.

Generally speaking, the abundance and geographical distribution of a species result from the balance between births, deaths, and movements across different environments. The distribution limits lie where the death rate begins to exceed the birth rate. When an invasive species enters a new habitat unaccompanied by its natural enemies, it often benefits from "ecological release" that allows the species to reach much higher population densities than would occur in its natural range where it is constrained by various predators and competitors. Box 7 suggests some general ecological rules of invasion.Species vary considerably in their potential for becoming invasive. An elementary set of "tools" has been developed for predicting which species of plants will invade and which will not, and the extent to which different systems are invaded (Box 9). This toolbox has not yet been applied systematically to insects, pathogens, or other taxa. Fundamentally, we are dealing with complex systems with numerous components involved, thus making it difficult to predict impacts with precision in the absence of detailed studies. Further, outcomes of invasions depend on the attributes of the invasive species as well as the vulnerability of the invaded systems, indicating the extreme complexity of such systems (Rejmanék et al., 2000).

5.2 How rapidly do species invade?

The rate of spread is a function of both reproduction and dispersal, with species that reproduce quickly and spread easily moving much more rapidly. For plants, determining the rate of spread requires knowledge of the rare dispersal events that can send plants over an abnormally long distance. While the rate of dispersal is critical, other factors such as age of reproductive maturity, disturbance frequency, habitat disturbance, and fecundity also are important. Seeds can be transported over long distances by agents such as water, wind, vehicles, or livestock, often at remarkably high speeds.

BOX 7

ECOLOGICAL RULES OF INVASION

- The probability of a species becoming invasive increases with the initial population size, so species introduced intentionally and cultivated (plants) or maintained under animal husbandry over a long period of time have greater likelihood of establishment.
- Species having larger native geographic ranges are more likely to be invasive than those with smaller native ranges.
- A species that is invasive in one country or location is should be considered as high risk of becoming invasive in an ecologically or climatically similar country or location.
- Species with specialised pollinators are unlikely to be invasive unless their pollinators are also introduced.
- Successful invasions generally require that the new habitat conditions are comparable to those at the point of origin, especially in terms of climate conditions.

5.3 What is the ecological impact of invasive alien species?

Every alien species that becomes established alters the composition of native biological communities in some way. Whether it becomes invasive

(and thus harmful) depends on the particular characteristics of the alien species, the vulnerability of the host ecosystem and chance. The changes to the state of ecosystems may be initiated by natural disturbance (storm, earthquake, volcanic eruption, fire, climate) or management regime, but are enhanced or accelerated by the invasion of alien species. The inter-linkages between land transformation and invasions are illustrated diagrammatically in figure 3.

The issue of establishment and spread of an alien species does not necessarily say anything about its potential ecological or economic impact. The ecological impact of the loss of biodiversity due to IAS depends to a large extent on the link between native species and their contributions to ecosystem functions, such as pollination, seed-dispersal, or hydrological cycles.

Whether the loss of any particular species or combination of species substantially affects a given function depends on the number of other native species that can support the function when the ecosystem is perturbed. Invasive species may undermine the buffering role played by ecological redundancy, though ecology has not yet provided authoritative advice on this question.

Data from countries where a species has previously invaded can provide useful information on invasion rate and speed, habitats prone to invasion, possible ecological and economic impacts as well as approaches to management. This is the basis for the Early Warning System being established under GISP Phase I (Lowe and Clout, 2000).

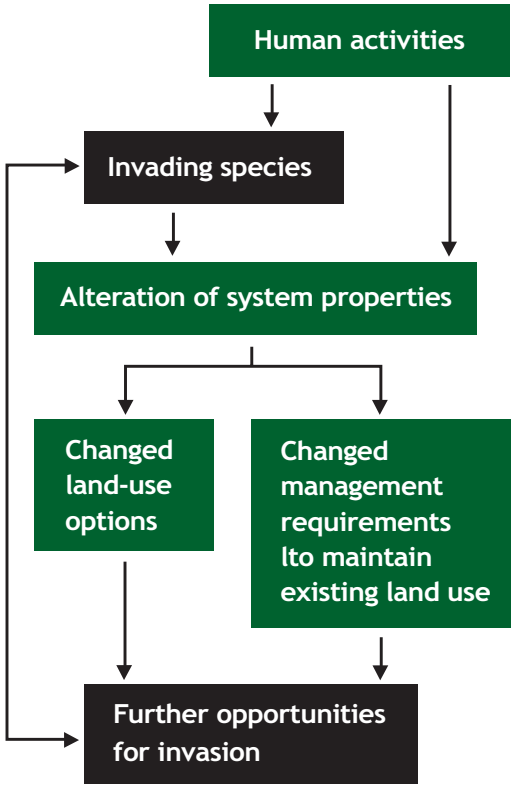
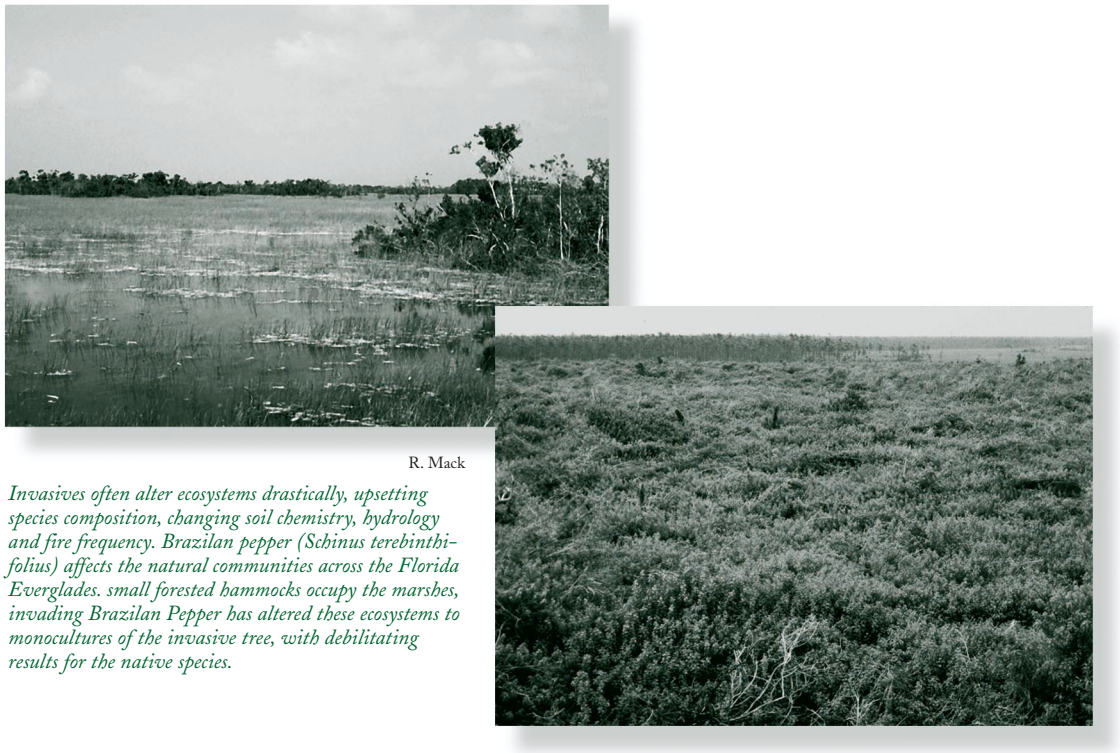


Figure 3.
Interrelationships between human activities, management of ecosystems and invasions (from Hobbs, 2000).



R. Mack

Invasives often alter ecosystems drastically, upsetting species composition, changing soil chemistry, hydrology and fire frequency. Brazilan pepper (Schinus terebinthifolius) affects the natural communities across the Florida Everglades. small forested hammocks occupy the marshes, invading Brazilan Pepper has altered these ecosystems to monocultures of the invasive tree, with debilitating results for the native species.

5.4 Which types of ecosystems are susceptible to IAS?

While all ecosystems (including those in well-protected national parks), can be invaded potentially, some appear more vulnerable than others. Evolutionarily and geographically isolated ecosystems, notably oceanic islands, are particularly vulnerable. Urban-industrial areas, habitats suffering from periodic disturbance, harbours, lagoons, estuaries and the fringes of water bodies, where the effects of natural and anthropogenic disturbances are often linked, are also particularly vulnerable to invasions (Kowarik, 1999). Systems with low diversity, for example some arid ecosystems, are thought by some to be more susceptible to invasion than species-rich systems with well-established species interactions (Baldacchino and Pizzuto, 1996). However, species-rich landscapes can be susceptible to a greater range of invaders because of the greater diversity of habitats typical of such landscapes (Levine and D'Antonio, 1999; Lonsdale, 2000).

We conclude that although virtually all ecological communities are susceptible to invasion to some degree, economic activities (e.g. forestry, agriculture) that disturb ecosystems increase the susceptibility of most ecosystems. Therefore, the continuing expansion of economic activities is likely to increase the susceptibility of ecological communities to invasion.

5.5 Conclusions

General ecological rules governing biological invasions developed under GISP Phase I are presented in Boxes 7 and 8. Understanding invasions depends on detailed knowledge of the species and habitats of interest, though of course this understanding builds on general properties of community structure. Experience suggests that extensive monitoring will be required to identify potential problems at a stage sufficiently early to enable an effective response. This makes it essential to take an adaptive management approach, with results from early interventions improving subsequent management investments.

The continuing expansion of economic activity is likely to increase the susceptibility of communities to invasion.

The source populations of potential IAS, the pathways and the vectors that follow the pathway, and the destination regions are in a constant state of change and flux, permitting many new opportunities for species to become established. As the rate of change continues to accelerate with global trade, climate change, tourism, and habitat modifications in the name of development, the dynamism of this system is likely to grow, thus requiring a growing capacity to manage the impacts of such changes.

BOX 8

KEY BIOLOGICAL POINTS FOR PREDICTING INVASIVENESS OF PLANTS

1. Within a genus, small genome size corresponds to plant invasiveness in disturbed land scapes.

2. Invasiveness of woody taxa in disturbed landscapes is associated with small seed mass, short juvenile period, and short intervals between large seed crops.

3. Vegetative forms of reproduction are an important factor, with the importance of this factor increasing with latitude.

4. Taxa belonging to genera not represented in the native flora are more likely to be invasive than alien taxa with close relatives in the native flora.

5. Plant species that depend on generalized pollinators and seed dispersers rather than specialised ones are more likely to be invasive.

6. Species with numerous, relatively small, soil-stored seeds are pre-adapted for human dispersal, and hence invasion.

Note: these generalisations, some of which explain rather than predict, are based on considerable data summarised in Rejmanek et al., 2000.

Chapter 6

Management and policy responses to the problem of invasive alien species

Management and policy responses to the problem of invasive alien species

At least partly because of ecological uncertainties and market imperfections, the risks of new introductions are typically borne by the state in the receiving country. These risks are determined by the quantity and effectiveness of resources committed to screening and the exclusion policy adopted (resources committed to detection and prosecution of non-compliance, incentive effects of the penalty regime, and so forth). Therefore, the management and policy responses to problems posed by IAS have become important concerns of many governments.

6.1 Introduction

The two broad categories of potentially invasive alien species – intentional and unintentional – may require quite different responses, with the intentional introductions demanding effective quarantine and impact assessment, while the unintentional invasions may require such measures as effective monitoring, fumigation, rapid response, early warning, and so forth.

Invasive species demand a special type of risk management, with the level of risk tending to increase as the management response declines. Prevention – not allowing a potentially invasive species to become established in the first place – is the first line of defence. Once an alien species has become a widespread invasive, the economic and often environmental costs of eradicating the invader, or even reducing it to a modest level, can be prohibitive, especially in landscapes that do not generate high economic returns. The main management responses after a species has invaded are mitigation and adaptation. Mitigation can reduce or eliminate the likelihood that a species will become established or spread, and decrease or eliminate the presence of an invader. Adaptation, on the other hand, involves changes in behaviour in order to reduce the impact of an invasive species. Prevention stops a bad event from happening; mitigation curtails the extent, duration, and impacts of a bad event; and adaptation reduces the consequence when a bad event is permitted to run its full course.

Thomas H. Fritts

An opportunistic predator, the Brown Tree Snake (Boiga irregularis) is thought to have hitchhiked to Guam on military aircraft. It is famous for the nearly complete extermination of Guam's native forest birds.

The control of invasive species has a strong public good element. Thus if control is left to the market, it is likely to be under-supplied. More important, the public good involved in the control of infectious diseases and many other invasive species is of the "weakest link variety", where the benefits from control to a whole society depend on the level of control exercised by the least effective member (Perrings and Williamson, 2000). For example, if control over a communicable disease involves eradication campaigns in all nations, that control will be only as good as the campaign run by the least effective nation.

The potential irreversibility of the damages of invasions and the uncertainty of the costs they may imply favour a precautionary approach to their management.

Generally speaking, biological invasions are low probability events with a high potential cost. Biological and economic factors can be used to assess the risk posed by a potential IAS, which then can be compared to the value of reducing the risk and the impact of additional risk of damages. The potential irreversibility of the costs of invasions and the uncertainty of the damages they may cause favour a precautionary approach to their management, tempered by a realistic appraisal of the costs and benefits of the options.

GISP has prepared a Toolkit for Prevention and Management of Invasive Alien Species. This guide is designed to aid in the elaboration and adoption of an effective national strategy by pointing to experiences in various nations (Wittenberg et al.; 2000). While the major IAS that are pests in agriculture, forestry, and human health have been dealt with for many decades using well-known methods for prevention, mitigation and adaptation, the application of these methods to species that threaten natural habitats are still at an early stage.

Since introduced species differ in their reproduction, rates of spread, and impacts, managers need to establish clear priorities directed at excluding, monitoring, containing, eradicating, or controlling IAS. Sound management strategies require an objective means for setting priorities,

BOX 9

TOOLS TO PREVENT INVASIONS:

- Public information.
- "Early warning", the capability to predict potential new invasion sites for an invasive species, and/or predict potential new invasive species for a region or site.
- Risk assessments and environmental impact assessments.
- National and international regulations on prevention measures and their enforcement with inspections and fees.
- Treatment of imported commodities, including through fumigation, immersion, spraying, heat and cold treatment, and pressure.
- As a last resort, trade restriction or prohibition consistent with the WTO Sanitary and Phytosanitary Agreement.

always a highly challenging task. For example, should a manager give higher priority to attacking the invader where it is most vulnerable, or to sites with high conservation value? Generally speaking, highest priority should go to infestations that are the fastest growing, most disruptive, and affect the most highly valued areas. Likelihood of success might also affect the priority. More detailed approaches to determining priorities are available in Wittenberg et al., 2000.

BOX 10

A SPECTRUM OF LISTS

Listing of species is one effective tool for dealing with IAS issues (Wittenberg, et al.; Shine, et al. 2000). Such lists can include:

- **Black lists**: species known to be invasive and so destructive that their introduction should be prohibited.
- **White lists**: species known on the basis of stringent criteria to have such a low probability of invasion that they can be introduced.
- **Grey lists**: the great majority of species whose probability of becoming invasive is unknown.

6.2 Prevention

Prevention is the first and least costly line of defence, using tools such as those listed in Box 9. Many countries have established means of preventing the import of human pathogens and pest species of agriculture and forestry, as the essential minimum of any invasive species management programme. Ideally, no alien species should be introduced without appropriate analysis and environmental impact assessment (EIA) procedures. Of course, this is relevant only for planned introductions and depends on an appropriate exclusion apparatus (salary and training of interception personnel, plus facilities such as fumigation chambers, inspection apparatus, and quarantine quarters). At least some of these costs might be borne by individuals who wish to profit by bringing in alien species. It is also possible that some members of the public might have benefited from a planned introduction that is disallowed by the prevention apparatus, but the risk assessment process presumably would ensure that the public costs outweigh the public benefits in such cases.

An important first step in prevention is to identify those alien species that may become invasive and therefore require special attention. These may be put on a "black list" and prohibited entry under national legislation. Species cleared for introduction through passing a risk assessment analysis can reasonably be declared as safe (put on a "white list"), though monitoring is still required to ensure that the prediction remains accurate over time. The potential invasiveness of the majority of the world's species is unknown and they should be placed on a "grey list" (Box 10). An important issue is when (how many years after arrival in a new region) a taxon can be declared to be "safe" (potentially non-invasive), bearing in mind that lag phases of many decades are not unusual. For example, the introduction of one species of plant used as a hedge in South Africa was widely supported because it could replace a species that was highly invasive, but a few decades later, the "safe" species had become a serious invader in some areas.

6.3 Mitigation

Mitigation can include **eradication** (eliminating the IAS completely); **containment** (keeping the IAS within regional barriers); or **suppression** (reducing population levels of the IAS to an acceptable threshold). A critical first step in a mitigation programme is to determine the management goal. For example, is it the intention to eradicate the IAS, or to reduce it to a certain level? If the latter, to which level will it be reduced, and how will it be maintained at such a level? The management objective should also specify the geographic areas for attention, in priority order. Once the objective has been agreed among all interested parties, a plan needs to be devised for achieving the objective, involving research, surveys, identification of control options, implementation, monitoring, and follow up.

Eradicating the entire population of an IAS within a managed area is often the most desirable output, and has proven feasible in situations (particularly on small islands). Because the cost of eradication increases dramatically the longer a species has become invasive, it is important that eradication be initiated as soon as potentially invasive species are detected. This can be done only if rapid response plans exist, along with appropriate government permits, trained personnel, equipment, and allocated funding (much like oil spill contingency plans available in many countries). Elements for an eradication plan are presented in Box 12.

BOX 11

GLOBAL DATABASE ON IAS AND DATABASE NETWORK

The GISP global database (http://www.issg.org/database) contains information on species, their taxonomy and ecology, their native and invaded distributions (including both habitat and location), impacts, contacts and references which can provide further information, plus reports on management methods. The database is:

- Searchable (including by geographic zone, species, and general category and has a predictive component (by habitat match with invaded range).
- Accessible to low-tech users (e.g. "user-friendly"), as well as quick and reliable.
- Designed so that additions can be made in future (e.g., it will be able to generate an "alert list" of recently introduced invasive species that are spreading rapidly across the region).

Future developments will include a network of databases on IAS, a contribution to the CBD Clearing House Mechanism, dissemination and local adaptation of the global invasive species database, and improved predictive, and early warning functions.

BOX 12

DESIGNING A SUCCESSFUL ERADICATION PROGRAMME

- Base the programme on science.
- Ensure that eradication of all individuals is achievable.
- Build support from the public and all relevant stakeholders.
- Ensure that the legal and institutional framework is sufficient for dealing with the issue.
- Secure sufficient funding.
- Ensure that all individuals of the target population are susceptible to the eradication technique being used.
- Ensure through prevention measures that the immigration of the target species into the area is zero
- Put in place a method to detect the last survivors.
- Include a subsequent monitoring phase to ensure that eradication has been achieved, and to prevent re-invasion.
- Ensure that methodologies/techniques are environmentally, socially and ethically acceptable.
- Include any necessary measures to restore ecosystems after eradication.

Numerous approaches to eradication or control have been developed, including mechanical, chemical, biological habitat management, and a combination of methods (Box 13). While eradication may involve high initial economic costs, if eradication is achieved it is invariably more cost-effective than any measure that requires continuous expenditure over long periods of time. On the other hand, eradicating the last few individuals might be exceedingly expensive; for example, malaria "eradication" programmes in tropical countries have proven very cost-effective in the early stages but the last stage has seldom been achieved. Prevention can also work against unintentional introductions, utilising measures such as border controls, quarantine, ballast water treatment, and so forth. An environmental impact assessment (EIA) of major development projects should include consideration of the extent to which conditions are established (through new roads, plantations, irrigation systems, and so forth) that will facilitate unintentional invasions, with a view to preventing them. To contribute to prevention, the GISP global database (Box 11) has sought to predict potential new invasions by matching habitat types with invaded range. In the future, it should be possible to add more factors (such as climatic suitability and pathways used), to further improve predictive capability and early warning potential. The high cost of eradication of an established IAS suggests that resources should be

devoted to early detection of potential invasive species before they can spread. Early detection of an invasive species of pathogen, plant, or animal can make the difference between being able to employ feasible offensive strategies (eradication) and the necessity of retreating to a defensive strategy that usually requires an open-ended financial commitment. The Early Warning System being developed under GISP could be a critical element of such a rapid response mechanism (Lowe and Clout, 2000).

If an invasive species is already widespread, then species-specific biological control may be the only practical way of going on the offensive. Biological control introductions are thought to be completely successful in 10 to 15% of efforts against arthropods, while perhaps 30 to 40% have achieved their objective against weeds. Economic analyses of successful biological control programmes have shown that they have a positive cost-benefit ratio, though some failed efforts have had disastrous ecological impacts. Modern safety standards of biological control are very rigorous, requiring a high specificity of the agents proposed and involving extensive laboratory and field screening tests. Biological control is often the only means that is self-sustaining over the longer term, and the least disturbing in areas highly valued for biodiversity (such as national parks).

6.4 Legislation to support management of IAS

Legal frameworks are essential to support efforts to manage IAS, working at both national and international levels. GISP has produced a Guide for Designing Legal and Institutional frameworks on IAS (Shine, Williams, and Gündling, 2000), seeking to provide an essential tool in this regard. Any legal framework at the national level needs to include adequate provisions for mitigating the impacts of IAS, a challenge that faces numerous constraints (e.g. lack of resources).

The "invasive" classification is quite separate from jurisdictional or administrative boundaries. If an alien species is invasive, it will not stay within the boundaries of the ecosystem, municipality or region to which it was introduced. One consequence for legal systems is that site-specific restrictions (for example, a prohibition on introducing alien species in protected areas) can never be more than a partial strategy for preventing or mitigating impacts of invasions. Thus, regional collaboration between countries in regard to IAS is essential. Numerous legal principles, approaches, and tools have been developed for dealing with problems of IAS (Shine, et al., 2000). Several of these are listed in Box 14.

BOX 13

CONTROL OF INVASIVE ALIEN SPECIES: A TOOLBOX

Many methods are available for controlling IAS, as detailed in Wittenberg et al (2000). These tools can be applied individually or in various combinations. Given the high complexity of the ecology of invasive species and habitats affected, control measures need to be applied with the fullest possible scientific understanding.

- **Mechanical control**: Involves directly removing the species by hand or with appropriate machines such as harvesting vehicles (e.g., for water hyacinth) or firearms (e.g., for large mammals), or traps (for animals).
- **Chemical control**: Involves the use of herbicides, insecticides, and rodenticides that primarily affect the target species, are delivered in a way that avoids the potential problem of resistance developing over time, and do not accumulate in the food chain. The development of pesticide-resistant strains of pests, diseases and weeds may reduce the effectiveness of the chemical management option for their control.
- **Biological control**: Involves the intentional use of populations of natural enemies of the target invasive alien species or other methods that include, for example, mass release of sterile males of the target species, inducing resistance in the host against the IAS that is attacking it, or releasing a natural enemy to control the IAS. It is essential to ensure that the species used for biological control does not in turn become itself invasive.
- **Habitat management**: Involves measures such as prescribed burning, grazing, and other activities.
- **Integrated pest management (IPM)**: Involves a combination of the methods described above, based on ecological research, regular monitoring, and careful coordination. IPM is likely to achieve the best results in many situations.

6.5 Conclusion

Controlling or eradicating IAS is not a management goal in itself, but only one means to achieve higher goals, such as the conservation of biological diversity, protection of human health, and prevention of economic loss. Elements of these goals might include habitat restoration, reintroduction of native species, preservation of relatively undisturbed ecosystems enabling natural succession rate and time, and establishment of sustainable use of ecosystem services for local people.

The classic method for evaluation of management options is benefit-cost analysis. This requires that the expected present value of the benefits of the control programme (that is, the net costs avoided by the control programme) are no less than the expected present value of the costs of control (the foregone benefits of the programme).

BOX 14

SOME LEGAL PRINCIPLES, APPROACHES, AND TOOLS FOR DEALING WITH INVASIVE ALIEN SPECIES

Precaution: lack of scientific certainty shall not be used as a reason to postpone measures to avoid or minimize a threat of significant reduction or loss of biodiversity (CBD).

Prevention: the protection of the environment is best achieved by preventing environmental harm rather than by attempting to remedy or compensate for such harm.

Permit system: permit (or licensing) systems provide a framework within which applications to introduce an alien species can be assessed or screened and an informed decision made before authorising an intentional import or release.

Polluter Pays Principle (Cost Recovery): the natural or legal person who is responsible for causing the introduction of the alien invasive species should bear the cost of prevention and control measures.

Public participation and access to information: planning and decision-making procedures on alien species issues are complex and require the involvement of all stakeholders, all sectors and at all levels.

Risk analysis processes: should identify the relevant risks associated with a proposed introduction or management measure.

Environmental impact assessment: like risk analysis, should be conducted before making a decision on whether or not to authorise a proposed introduction of an alien species.

While strategies to control invasive species are faced with the problem of uncertainty in the effectiveness of different management options, it is still reasonable to evaluate public investment in management options using a benefit-cost framework (Box 15). But where the costs of error are potentially very high, the management effort must protect the capacity of the system to absorb the stresses and shocks of biological invasions.

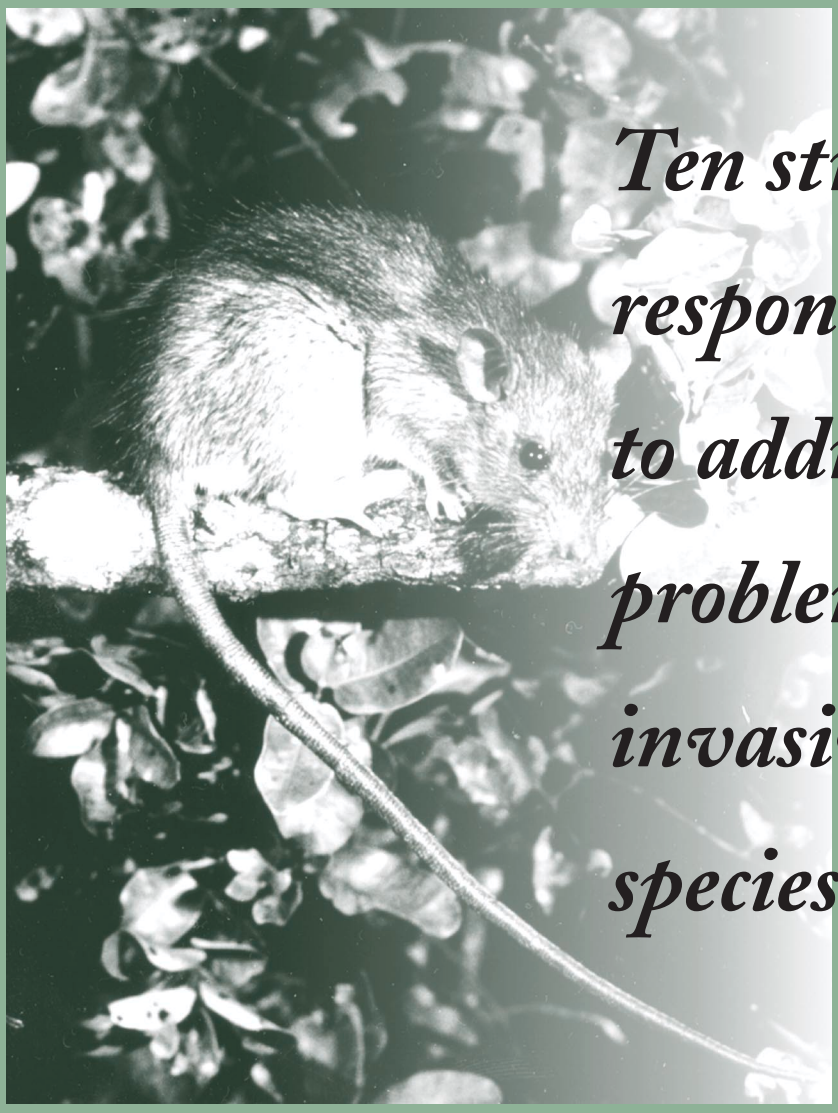
BOX 15

BENEFIT - COST RATIOS FOR MANAGING IAS IN THE USA (BASED ON OTA, 1993) ($US IN MILLIONS)

Invasive alien species	Benefits of control/ prevention/eradication	Cost (US$)	Ratio Benefit - cost
Melaleuca	183.0	16.0	11.4/1
Water hyacinth	3.8	.28	13.6/1
Sea lamprey	296.0	9.8	30/1
Alfalfa blotch leafminer	17.0	2.0	8.5/1
Purple loosestrife	53.0	2.0	26.5/1
Mediterranean fruitfly	1,829.0	93.0	19.6/1
Foot and mouth disease	25,275.0	1013.0	25/1
Siberian log imports	64,704.0	39.0	1659/1

Agriculture/Australia

The Mediterranean fruit fly is one of the most threatening agricultural pest worldwide, it has a host range of over 250 species of fruit bearing plants.



Ten strategic responses to address the problem of invasive alien species

Ten strategic responses to address the problem of invasive alien species

Under the Convention on Biological Diversity, the Conference of Parties agreed to a set of interim Guiding Principles, to which GISP has contributed. Considering these principles and incorporating the efforts of numerous experts who contributed to the final reports of the GISP Components during the Phase I Synthesis Conference held in Cape Town, South Africa in September 2000, we have developed ten strategic responses. These elements are intended to guide policy-makers in responding to the growing challenge of invasive alien species.

ELEMENT 1

Build management capacity

Successfully addressing the problem of IAS requires both national will and capacity to act. Because the problem is a global one, involving virtually all nations, an adequately funded and vigorous international response to building management and operational capacity in all countries clearly is a high priority. At a national level, capacity-building initiatives can draw upon experiences of other countries, the GISP Toolkit of Best Prevention and Management Practices, and other resources. Such initiatives should include elements such as the following:

- Designing and establishing a "rapid response mechanism" to detect and respond immediately to the presence of potentially invasive species as soon as they appear. At a national level, this requires (1) establishment of easily accessible funds for emergency actions; (2) regulatory support for rapid action; and (3) interdepartmental co-ordination on IAS that can quickly identify and give authority to a lead agency or agencies. (Proposed GISP role: provide technical support for such a mechanism).
- Designing educational programmes to build capacity, including training courses aimed at agency field staff, managers, specialists and policy makers. (Proposed GISP role: technical support to training).
- Building the capacity to formulate and implement educational programmes aimed at community empowerment (e.g., in early detection and control) and at developing school and university curricula; and creating academic chairs and student fellowships in invasive species biology. (Responsibility: educational institutions).
- Developing national-level institutions that bring together biodiversity specialists with agricultural quarantine specialists to co-operate in addressing the provisions of the CBD and other relevant agreements (e.g., building environmental elements into pest risk assessment). Existing staff may require retraining in invasive alien prevention and management skills. (Responsibility: governments).
- Establishing IAS specialist positions in natural resource management agencies. (Responsibility: governments).
- Building basic border control and quarantine capacity, ensuring that all those involved in agricultural quarantine, customs, or food inspection are made aware of the provisions of the CBD and its Biosafety Protocol, and the implications of these provisions for their work. (Responsibility: governments).

ELEMENT 2

Build research capacity

The current knowledge on IAS must be further developed with a cross-sectoral and multi-disciplinary approach in order to provide the tools needed to address this pervasive issue. Considerations for such an approach may include the following foci:

Institutional frameworks and collaboration

- Strengthening infrastructure for research on IAS (e.g., systematics, taxonomy, and ecology) at national and regional levels. An international committee to correlate and manage updated taxonomic nomenclature for all IAS would be a useful resource.
- Directing existing relevant research resources and products towards a focus on IAS, by informing and engaging academic and national research institutions and exchange programmes.
- Building academic groups – "*centres of excellence*" – on invasive biology and encouraging exchange and collaboration in formulation of research approaches.
- Developing a mechanism for mitigation and monitoring of IAS through cross-sectoral and interagency integrative research and management on an international scale.

Assessment and Prediction

- Building the capacity to identify, record and monitor invasions and provide current lists of potential and established IAS.
- Determining the relative contribution of anthropogenic factors, natural factors, and their interaction, to the spread of IAS.
- Improving the understanding of how and why species become established and investigate species that have the potential to become invasive and ecosystems that may be particularly vulnerable to invasion; building an understanding of the mechanisms controlling lag times in the development and establishment of IAS.

Management: early detection, assessment, prevention and control

- Building research networks that incorporate the risk assessment, risk management and research approach.
- Developing and improving techniques to eradicate and control IAS. Considerations include developing species-specific toxins and diseases; improving the basis on which biological control strategies are evaluated; provide consideration to the limiting factors that affect the spread and the geographic distributions of taxa.
- Developing better methods for excluding or removing alien species from traded goods, packaging material, ballast water, personal luggage, aircraft and ships and other methods of transport.
- Developing methods for ecosystem restoration and sustainability following control measures; consider utilisation of native taxa in erosion control and restoration efforts in planning and collaboration with sectors (e.g. agroforestry, horticulture) and agencies.

ELEMENT 3

Promote sharing of information

Considerable information about IAS is available. GISP has identified nearly 120 major sources of information on invasive species that are accessible electronically (Boudjelas, 2000). The information that could alert management agencies to the potential dangers of new introductions is either not well known, or is not widely shared or available in an appropriate format to enable governments to take prompt action (assuming they have the resources, necessary infrastructure, commitment and trained staff to do so). Information sharing therefore is essential. The following actions will facilitate this:

- Building a distributed information system of linked regional and national databases on invasive alien species, building on various sources of information (e.g., IABIN, IUCN/ISSG Aliens Listserver). The Global Invasive Alien Species Information System should service a distributed network, set data standards and facilitate the input and sharing of data. It should work in multiple languages and promote wide distribution of information to all interested parties using all available technology. (Proposed GISP role: manage the Global Invasive Alien Species Information System (GIASIS)).

- Developing the GISP Early Warning System (EWS), including notification of new and/or predicted occurrences of invasive species. (Proposed GISP role: develop the EWS).
- As part of GIASIS, establishing a database of failure and success of different eradication and control methods for invasive species to ensure that all can learn from the experience, and link this to the GISP toolkit. (Proposed GISP role: establish the database).

ELEMENT 4

Develop economic policies and tools

Species invasions are a consequence of economic decisions and have economic impacts. However, the costs of invasions are seldom reflected in market prices. While prevention, eradication, control, mitigation and adaptation all yield economic benefits, they are public goods. If left only to the market, the control of IAS, like the control of communicable human diseases, will be inadequately provided for. Because biological invasions often indicate market failure, an important part of any strategy to manage IAS is to make markets work for conservation wherever possible, and to provide alternate solutions if markets do not exist and cannot be created. Therefore, GISP encourages countries to incorporate economic principles into their national strategies for addressing IAS, building on the following main principles:

- *User pays*: make those responsible for the introduction of economically harmful invasive species liable for the costs they impose.
- *Full social cost pricing*: ensure that the prices of goods and services whose production or consumption worsens the damage of invasives reflect their true cost to society.
- *Precautionary principle*: because of the potentially irreversible and high costs of invasives, it is important to base management and policy on the precautionary principle, which states: "when an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically". (Raffensperger, Carolyn, et al 1999).
- *Protection of the public interest*: since the control of harmful invasives yields benefits that are a public good, it requires public investment in prevention, eradication, control, mitigation and adaptation.
- *Subsidiarity*: operate policies and management at the lowest level of government that can effectively deal with the problem.

Particular policies that governments may wish to develop to reflect these principles include:

- *Developing appropriate property rights*: ensure that use rights to natural or environmental resources include an obligation to prevent the spread of potential IAS;
- *Estimating social costs*: assess the economic costs of actual or potential IAS;
- *Assigning liability*: require importers/users of potential IAS to have liability insurance to cover the unanticipated costs of introductions or of activities that risk introductions;
- *Promoting empowerment*: enable people injured by the spread of IAS to seek redress;
- *Applying price-based instruments*: to ensure that importers/users of known IAS take account of the full social cost of their activities, apply economic instruments such as commodity taxes, differential land use taxes, user charges or access fees;
- *Applying precautionary instruments*: where the risk of damage depends on the behaviour of importers/users of IAS, apply precautionary instruments such as deposit-refund systems or environmental assurance bonds.

ELEMENT 5

Strengthen national, regional and international legal and institutional frameworks

Until recently, national legal measures have evolved in a reactive and piecemeal manner, responding to new problems and pathways relating to IAS. However, isolated unilateral action by individual States can never be sufficient to manage the full range of activities and processes that generate invasions. Coordination and cooperation between the relevant institutions are necessary to address possible gaps, weaknesses and inconsistencies, and promote greater harmonization between the many international instruments

that address IAS. Strategies should aim to develop or strengthen legal and institutional frameworks at two major levels: national; and regional and global.

Developing and strengthening national legal and institutional frameworks should include:

- Reviewing relevant policies, legislation and institutions to identify conflicts, gaps and inconsistencies; and strengthen or develop effective national measures for the prevention, eradication, and control alien species.
- Considering the establishment of a coordinating mechanism as well as a process between different levels and departments of government.
- Ensuring the participation and access to relevant information by all stakeholders, including local communities, in the development and implementation of laws and policies;
- Ensuring that legislation extends to all ecosystems and biomes within the national territory, especially vulnerable ecosystems, such as geographically or evolutionary isolated ecosystems, oceanic islands, aquatic ecosystems, and protected areas;
- Ensuring that all sectors and the full range of activities, vectors, and pathways are covered;
- Providing control measures to regulate and minimize the introduction of IAS, at the point of origin (export), destination (import), or both;
- Strictly regulating the movement and release of alien species domestically, especially in or near vulnerable ecosystems, between islands, and to protected areas;
- Providing surveillance, monitoring and early warning systems to detect the introduction of IAS and take emergency action, as necessary and appropriate;
- Establishing an appropriate set of rights and responsibilities to address the impact of IAS along with supporting institutions, compensation mechanisms, and incentives and disincentives.

Promoting coordination and cooperation at the international and regional level should involve:

- Encouraging a detailed review of possible differences, inconsistencies or gaps between the mandates of major international and regional instruments relevant to IAS, with a view to encouraging resolution of these;
- Continuing to integrate and promote biodiversity in international standards and processes, including risk analysis;
- Continuing to develop international guidance on standards and methodologies applicable to IAS;
- Encouraging a full discussion of a more comprehensive international approach;
- Supporting the work of the IMO to develop a legal instrument on marine IAS and encouraging similar developments in other sectors.

ELEMENT 6

Institute a system of environmental risk analysis

Risk Analysis (RA) and Environmental Impact Assessment (EIA) procedures have already been adopted in many countries and mandated by certain international instruments. The challenge now is to apply these to address the prevention, eradication and control of IAS. This should involve shifting the burden of proof to those individuals proposing the intentional introduction of a potentially invasive species. Risk analysis measures should be used to identify and evaluate the relevant risks of a proposed activity regarding alien species, and determine the appropriate measures that should be adopted. EIA plays an important role in the decisions to undertake specific processes or activities. Decision-makers should ensure the use of strategic and/or project-specific EIA in assessing the impact, long-term and short-term, of alien species introductions. To ensure the effective use of RA and EIA, decision-makers should consider:

- Examining the WTO, IPPC, IMO, and other partners to promote the extension of risk analysis criteria and methods to all invasive taxa.

- Building on work undertaken by the plant and animal protection community to develop a rigorous process of risk analysis in relation to any deliberate introduction of species (not just between countries, but within a country or region as well), including detailed analysis of the balance between benefits and costs. This assessment would allow more informed decision-making in relation to invasive alien species introduction, control and management.

- Developing criteria to measure and classify impacts of alien species on natural ecosystems, including detailed protocols for assessing the likelihood of invasion in specific habitats or ecosystems. Where prediction protocols exist for landscapes comprising mosaics of ecosystems, predictions for the most vulnerable system in the landscape should dictate management decisions.

- Developing tools to factor invasive species into the decision-making processes regarding land use planning and development.

- Investigating ways in which strategic and project-specific EIA can be applied to unintentional introductions. For instance, assess large engineering projects, such as canals, tunnels and roads that cross bio-geographical zones, that might have the effect of mixing previously separated flora and fauna. (Responsibility: governments).

ELEMENT 7

Build public awareness and engagement

Active public engagement is critical to successful invasive species management. This strategy is intended to help states and organizations engage the public successfully and coordinate their efforts for greatest global benefit, leading to an informed public that supports ongoing actions to reduce the threat of IAS, and key stakeholders who are actively engaged in implementation of IAS solutions. Attaining these desired outcomes will require:

- Developing public awareness campaigns to support IAS management, including sharing information and coordinating information as appropriate to avoid contradiction and maximise efficiency. (Responsibility: states and organizations).

- Using appropriate pilot projects on IAS with high priority or visibility, or those affecting important native species, as a basis for raising public awareness, validating investment in rapid response and management systems and building capacity through "learning by doing". (Responsibility: management agencies).

- Engaging key stakeholders, communities and neighbours in creating solutions to the problem by linking IAS strategies wherever possible to integrated development programmes, for example to programmes that emphasize poverty alleviation measures and other established societal priorities (Responsibility: NGOs and governments);

- Building the capacity of local communities and groups to implement IAS management measures where they live (Responsibility: local governments).

- Sharing experience in this strategy with other nations, states and organizations through documentation, staff exchanges, and by other means (Responsibility: governments and the Clearing House Mechanism of the CBD).

ELEMENT 8

Prepare national strategies and plans

The problems posed by IAS are not simply the responsibility of a ministry of environment or a natural resource management department. Rather, the problem is spread through many economic sectors, both public and private. As with biodiversity, successfully addressing the problems of IAS will require effective collaboration among these various institutions. Drawing on experience gained through preparing National Biodiversity Strategies and Action Plans (NBSAPs), relevant agencies should collaborate, through an open consultative process, to prepare strategies and action plans for dealing with IAS, or build elements for doing so into existing NBSAPs.

Elements to include in such strategies and plans should include:

- Promoting cooperation within each country among sectors whose activities have the greatest potential to introduce IAS, including the military, economic development, forestry, agriculture, aquaculture, transport, health, tourism, and water supply.

- Coordinating the activities of government agencies with responsibility for human health, animal health, plant health, transport,

tourism, trade, protected areas, wildlife management, water supply and other fields relevant to invasive alien species.

- Encouraging collaboration between different scientific disciplines and approaches that can contribute to addressing invasive species problems, and combining these to produce a framework for the assessment of vulnerability of systems or geographical regions to invasive species. Multi-disciplinary approaches should be promoted in this regard.
- Ensuring that the necessary information and policy guidance is provided to national delegations to sessions of the World Trade Organization and others responsible for setting world trade policy, with a particular focus on the Sanitary and Phytosanitary Agreement (SPS).
- Applying experience in agricultural, forestry, and human health systems to combating IAS in natural systems. For example, use quarantine facilities for agriculture to serve more broadly for all environmental pests.
- Fully involving environmental and developmental non-governmental organisations as means to address IAS issues. (Responsibility: governments. GISP role: providing technical advice).

At the regional and international levels, the relevant international organizations and international NGOs could be more effective in addressing IAS problems by building collaboration and cooperation. This could include:

- Establishing close links between public health agencies (including World Health Organization) dealing with invasive pathogens and those dealing with other parts of the IAS issue, with a view to exchanging information about effective management approaches. (Responsibility: UN system).
- Working with the wide range of relevant international trade authorities and industry associations, with the goal of significantly reducing the risk that trade, travel, and tourism will facilitate the introduction and spread of IAS. (Responsibility: World Trade Organization).
- Encouraging and contributing to the development of collaborative industry improved standards of practice, guidelines or codes of conduct, which minimize or eliminate unintentional introductions; or strengthen these where they already exist. (Responsibility: Private sector).
- Encouraging organizations like the International Tropical Timber Organization (ITTO), the World Tourism Organization, and the Food and Agriculture Organization (FAO), the Consultative Group on International Agricultural research (CGIAR), UNICEF, UNEP and UNESCO to build invasive alien species elements into their programmes. (Responsibility: governments).

ELEMENT 9

Build invasive alien species issues into global change initiatives

Human activities are changing the Earth in unprecedented ways. These changes are altering the atmospheric composition (e.g. CO2 concentrations, nitrogen deposition), changing the climate (e.g. rising temperatures, increased incidence of episodic storms), increasing the utilisation of natural resources and changing land use (including fragmentation and altered fire regimes), and deliberately and inadvertently moving species around the globe. Global change is likely to result in increased opportunities for the transport and establishment of IAS. The interactions of IAS with other elements of global change may occur in complex and unpredictable ways, acting as drivers of further change. Global change results from the cumulative impacts of local decisions, and hence the issues need to be addressed both at international and local levels. Key actions in response to this will include:

- Articulating the interactions between IAS and other elements of global change (e.g. climate change, land use change).
- Quantifying the current and anticipated impacts of IAS at global and regional scales, for incorporation into other global change projections.
- Using scenario building as a means of incorporating uncertainty into projections of interactions between different elements of global change.
- Ensuring that relevant international organizations with responsibility for global change issues (e.g. ICSU, IGBP, WHO, UNEP, UNESCO, WWF and FAO) include IAS as a component of global change, directly and through their member states.

- Responding to global change issues without increasing the risks derived from IAS – e.g. carbon sequestration, biomass energy, mitigation of degraded lands. (Responsibility: governments).

ELEMENT 10

Promote international cooperation

A wide range of approaches, strategies, models, tools, and potential partners are available for international co-operation. The most relevant approach varies for each situation. The tables on page 38 provide a basis for working with other international agreements and institutions on the development of effective tools and mechanisms on the introduction, eradication and control of invasive alien species.

Elements that would foster better international cooperation might include:

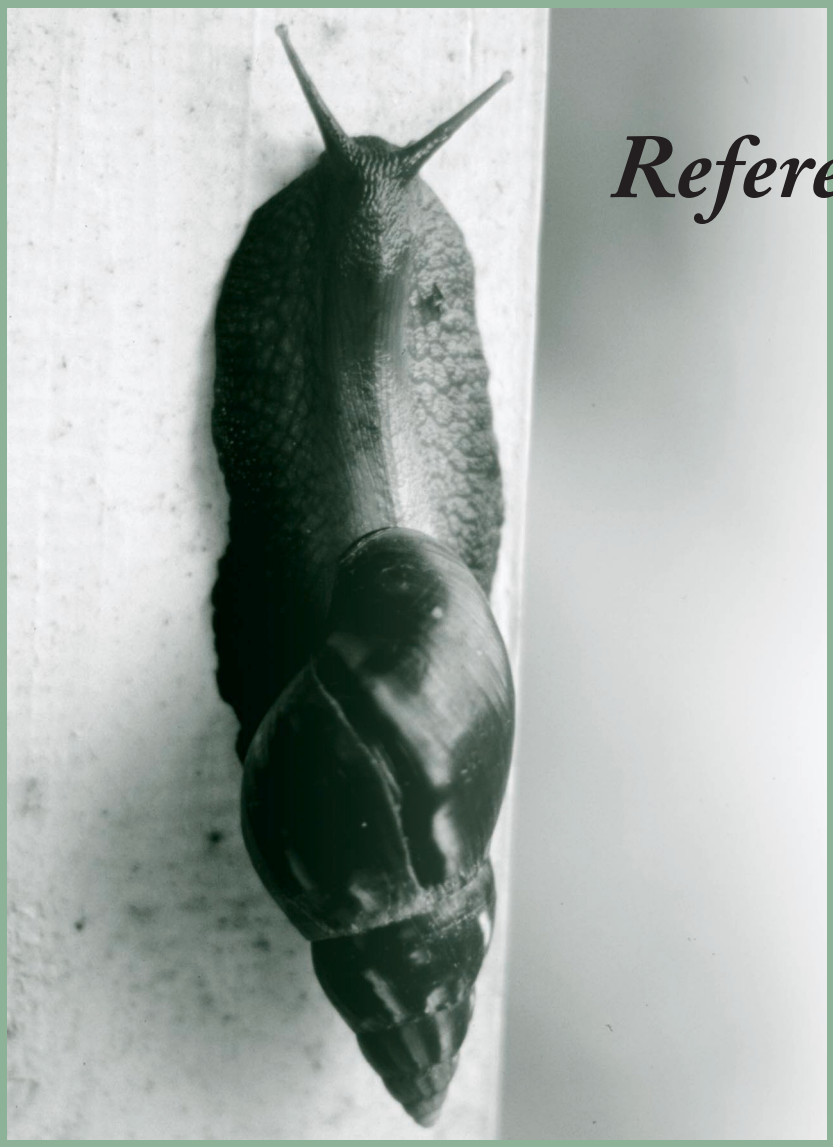
- Developing an international vocabulary, widely agreed and adopted. Note that the IPPC is currently promoting an initiative to encourage national agencies to employ the internationally accepted phytosanitary vocabulary to facilitate communication. Wherever available, internationally agreed terminology and standards should be used in implementing legislation and regulations.
- Developing cross-sectoral collaboration among international organizations involved in trade, tourism and transport.
- Developing harmonization and linkages among the international institutions dealing with phytosanitary, biosafety, and biodiversity issues related to invasive alien species and supporting these by strong linkages to coordinated national programmes and their focal points. (Responsibility: governments).
- Developing joint work programmes among relevant conventions, including CBD, Ramsar Wetlands of International Importance, World Heritage, International Trade in Endangered Species of Wild Flora and Fauna (CITES), Migratory Species and others.

Invasions often are relevant to biogeographical regions, not just jurisdictional country boundaries. Hence neighbouring countries need to cooperate, and in general, regional approaches to management need to be encouraged, including:

- Working towards regional IAS strategies
- Identifying regional information requirements
- Fostering regional cooperation in risk assessment, prevention, eradication or control
- Promoting regional cooperation in technologies/capacity building (Responsibility: Regional Cooperation organizations).
- Establishing at an international level a "Centre for Invasive Alien Species" to provide rapid diagnosis and information on management of the spread and occurrence of new alien species threats. It would also support capacity sharing efforts between countries in IAS prevention and management, and regional quarantine capacity and systems.

Because IAS have become an issue of considerable global concern, bi-lateral and multi-lateral donor agencies should be encouraged to:

- Support activities relating to sectoral and national policies on invasive species;
- Support better coordinated approaches at the national level as a way to strengthen capacity for international cooperation;
- Encourage inter-governmental cooperation in prgrammes they fund; and
- Review planning processes with a view to ensuring that the programmes they support will not include the intentional introduction of IAS and will minimise unintentional introductions (Responsibility: Development assistance agencies).



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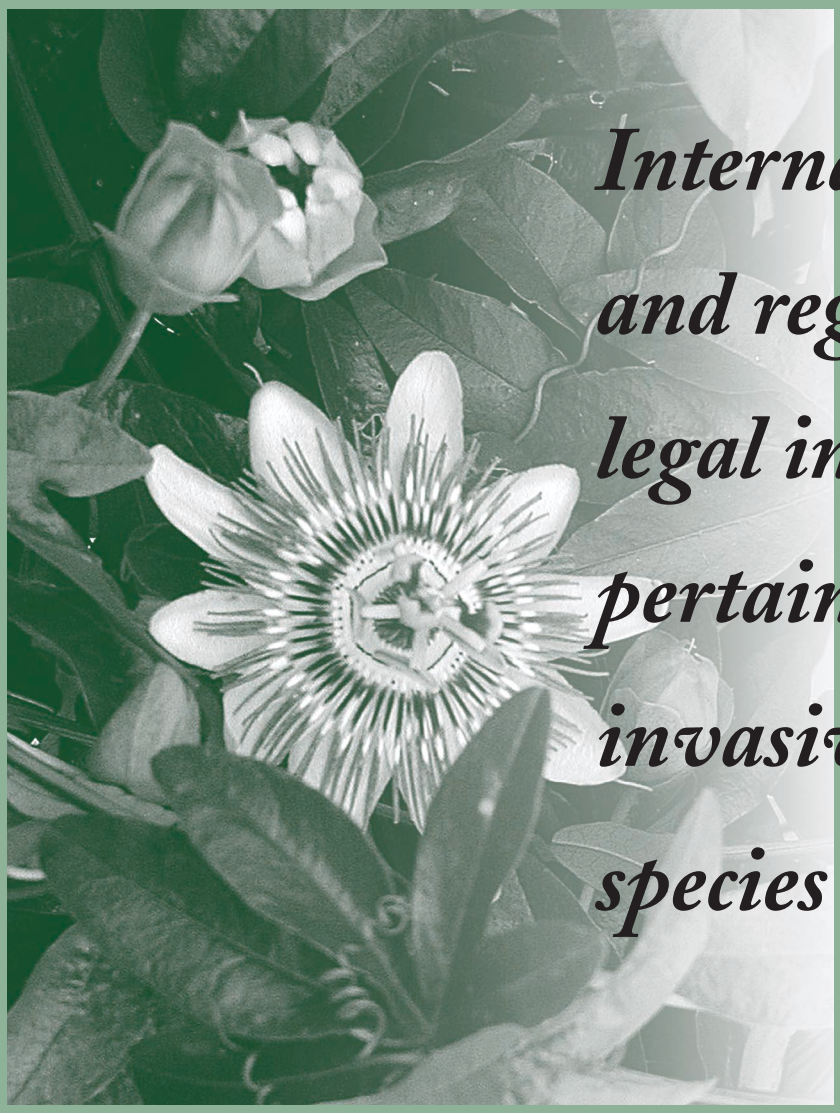

International and regional legal instruments pertaining to invasive alien species

International and regional instruments and institutions pertaining to alien invasive species

Instrument/Institution	Relevant Provisions/Decisions/Resolutions
1. Convention on Biological Diversity (Nairobi, 1992) http://www.biodiv.org	Article 8 (h). Parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species".
2. Cartegna Protocol on Biosafety to the Convention on Biological Diversity (Montreal, 2000) http://www.biodiv.org	Protocol's objective is to contribute to ensuring adequate level of protection in the safe transfer, handling and use of living modified organisms resulting from modern biotechnology that may have adverse effects on the conservation and sustainable use of biological diversity.
3. United Nations Convention on the Law of the Sea (Montego Bay, 1982) http://www.un.org/Depts/los/losconv1.html	Article 196. States to take all measures necessary to prevent, reduce and control the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes.
4. The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar, 1971) http://www.ramsar.org	COP7 -- Resolution VII.14 on Invasive Species and Wetlands
5. Convention on Migratory Species of Wild Animals (Bonn, 1979) http://www.wcmc.org.uk/cms/	Range State Parties of Endangered Migratory Species (Annex 1) to prevent, reduce or control factors that are endangering or likely to further endanger the species, including exotic species. (Article III (4)(c)). Agreements for Annex II Migratory Species to provide for strict control of the introduction of, or control of already introduced exotic species detrimental to the migratory species (Article V (5)(e)).
6. Agreement on the Conservation of African-Eurasian Migratory Waterbirds (The Hague, 1995) http://www.wcmc.org.uk/cms/aew_bkrd.html	Parties to prohibit the deliberate introduction of non-native waterbird species into the environment and measures to prevent the unintentional release of such species if this would prejudice the conservation status of wild fauna and flora; when non-native waterbird species have already been introduced, Parties to prevent them from becoming a threat to indigenous species. (Article III(2)(g)), Action Plan §2.5: Parties to prohibit non-native animal and plant introductions if detrimental to listed species, to prevent accidental escape of captive non-native birds, and to ensure that already introduced species do not threaten listed species.
7. Convention on the Law of Non- navigational Uses of International Watercourses (New Work, 1997) http://www.un.org	Watercourse States shall take all necessary measures to prevent the introduction of species, alien or new, into an international watercourse. (Article 22).
8. International Plant Protection Convention (Rome, 1951, as amended in 1997) http://www.fao.org/legal/treaties	Creates an international regime to prevent spread and introduction pests of plants and plant products through the use of sanitary and phytosanitary measures by Contracting Parties. Parties establish national plant protection organisations and agree to cooperate on information exchange and on the development of International Standards for Phytosanitary Measures. Regional agreements for Europe and the Mediterranean, the Asia-Pacific, Near East, Pacific, Caribbean, North American, South America and Africa.

Instrument/Institution	Relevant Provisions/Decisions/Resolutions
9. Plant Protection Agreement for the Asia and Pacific Region (Rome, 1956) http://www.fao.org/legal/treaties	Contracting Governments to prevent the introduction into and spread within the South East Asia and Pacific Region of plant diseases and pests. A supplementary agreement under Article III of the IPPC.
10. Agreement for the Establishment of the Near East Plant Protection Organisation (Rabat, 1993) http://www.fao.org/legal/treaties	Promotes implementation of the provisions of the IPPC with particular attention to measures for the control of pests, and advises Governments on the technical, administrative and legislative measures necessary to prevent the introduction and spread of pests of plants and plant products.
11. Convention for the Establishment of the European Mediterranean Plant Protection Organisation (Paris, 1951) http://www.fao.org/legal/treaties	Organisation to act, in agreement with FAO, as a recognised regional plant protection organization under the IPPC; to advise Member Governments on the technical, administrative and legislative measures necessary to prevent the introduction and spread of pests and diseases of plants and plant products.
12. Phytosanitary Convention for Africa (Kinshasa, 1967)	Heads of African States and Governments of the Organization of African Unity, to (a) prevent the introduction of diseases, insect pests, and other enemies of plants into any part of Africa; (b) eradicate or control them in so far as they are present in the area; and (c) prevent their spread to other territories within the area.
13. Agreement on the Application of Sanitary and Phytosanitary Measures (Marakech, 1995) http://www.wto.org/english/tratop_e/sps_e/spsagr.htm	A supplementary agreement to the WTO Agreement. Applicable to all sanitary and phytosanitary measures directly or indirectly affecting international trade.
14. International Health Regulations (Geneva, 1982) (adopted by the 22nd World Health Assembly in 1969 and amended by the 26th World Health Assembly in 1973, and the 34th World Health Assembly in 1981) http://www.who.int/emc/IHR/int_regs.html	To ensure maximum security against the international spread of diseases with a minimum interference with world traffic. Regulations strengthen the use of epidemiological principles as applied internationally, to detect, reduce or eliminate the sources from which infection spreads, to improve sanitation in and around ports and airports, to prevent the dissemination of vectors and to encourage epidemiological activities on the national level
15. Agreed Measures for the Conservation of Antarctic Fauna and Flora (Brussels, 1964) http://www.antcrc.utas.edu.au/opor/treaties/	Participating governments shall prohibit introduction of non-indigenous plants and animals into the Treaty Area except in accordance with a permit. Permits to be drawn in terms as specific as possible and issued to allow importation only of the animals and plants listed in Annex C (Article IX (1-4).
16. Protocol to the Antarctic Treaty on Environmental Protection (Madrid, 1991) http://www.antcrc.utas.edu.au/opor/treaties/	No species of animal or plant not native to the Antarctic Treaty Area to be introduced onto land or ice shelves, or into water of the Antarctic Treaty Area, except in accordance with a permit. (Annex II, Article 4(1))
17. Convention on the Conservation of Antarctic Marine Living Resources (Canberra, 1980) http://www.antcrc.utas.edu/opor/treaties	Parties to prevent changes or minimise the risk for changes in the marine ecosystem not potentially reversible over two or three decades, based on available knowledge including the effect of the introduction of alien species.
18. Convention Concerning Fishing in the Waters of the Danube (Bucharest 1958)	Acclimatisation and breeding of new fish species, other animals and aquatic plants prohibited in Danube waters without consent of Convention Commission (Annex Part V Article 10).

Instrument/Institution	Relevant Provisions/Decisions/Resolutions
19. Convention on the Conservation of European Wildlife and Natural Resources (Bern, 1979) http://www.coe.fr/eng/legaltext/104e.htm	Each Contracting Party undertakes to strictly control the introduction of non-native species. (Article 11(2)(b))
20. Benelux Convention on Nature Conservation and Landscape Protection (Brussels, 1982) http://sedac.ciesin.org/pidb/texts/benelux.landscape.protection.1982.html	Parties to prohibit introduction of non-native animal species into wild without authorisation from national authority; pre-introduction assessment required; communications between parties about planned introductions. (Benelux Council of Ministers Decision 17.10.83)
21. Protocol for the Implementation of the Alpine Convention in the Field of Nature Protection and Landscape Conservation (Chambery, 1994)	Parties guarantee that species of wild fauna and flora not native to the region in the recorded past are not introduced; exceptions possible when introduction needed for specific use will not "disadvantage" nature and landscape. (Article 17).
22. Protocol Concerning Mediterranean Specially Protected Areas (Geneva, 1982) http://sedac.ciesin.org/pidb/texts/acrc/mspecp.txt.html	Parties to prohibit the introduction of exotic species into marine protected areas, regulate acts likely to harm or disturb the fauna or flora, including the introduction of indigenous zoological or botanical species. (Article 7)
23. Protocol Concerning Specially Protected Areas and Biological Diversity in the Mediterranean (Barcelona, 1995) http://sedac.ciesin.org/pidb/texts/	Parties to regulate the introduction of any species not indigenous to the specially protected area in question, or of genetically modified species (Article 6). Parties to regulate the intentional or accidental introduction of non-indigenous or genetically modified species to the wild and prohibit those that may have harmful impacts on the ecosystems, habitats or species in the area to which the protocol applies (Article 13(1)). Parties to eradicate species that have been introduced when it appears that such species cause or are likely to cause damage to ecosystems, habitats or species. (Article 13(2).
24. ASEAN Agreement on the Conservation of Nature and Natural Resources (Kuala Lumpur, 1985) http://sunsite.nus.edu.sg/apcel/kltreaty.html	Parties endeavour to regulate and, where necessary, prohibit the introduction of exotic species. (Article 3(3)(c)).
25. Protocol for the Conservation and Management of Protected marine and Coastal Areas of the South East Pacific (Paipa, 1989)	Parties to take measures to prevent or reduce and control the extent possible the introduction of exotic species of flora and fauna, including transplants. (Article (VII (2)).26. Convention on the Conservation of Nature in the South Pacific (Apia, 1976) http://sedac.ciesin.org/pidb/texts/nature.south.pacific.html
26. Convention on the Conservation of Nature in the South Pacific (Apia, 1976) http://sedac.ciesin.org/pidb/texts/nature.south.pacific.htm	Parties shall carefully consider the consequences of deliberate introduction into ecosystems of species not previously occurring therein. (Article V (4)).
27. African Convention on the Conservation of Nature and Natural Resources (Algiers, 1968) http://www.unep.org	In any strict nature reserve or national park, Parties to take measures against any act likely to harm or disturb the fauna and flora, including the introduction of zoological or botanical specimens, whether indigenous or imported, wild or domesticated, is to be strictly prohibited. (Article III (4)(a)(ii) and (b)).
28. Agreement for the Preparation of a Tripartite Environmental Management Programme for Lake Victoria (Dar es Salaam, 1994)	Kenya, Tanzania and Uganda agree to implement a 5 year programme to strengthen regional environmental management of Lake Victoria including control of water hyacinth; biological control to proceed when environmental risks are found acceptable by national authorities; other forms of control to be explored. (Article 1, Attachment I, para. 7)

Instrument/Institution	Relevant Provisions/Decisions/Resolutions
29. Convention for the Establishment of the Lake Victoria Fisheries Organization (Kisumu, 1994)	Organisation to consider and advise on the effects of direct or indirect introduction of any non-indigenous aquatic animals or plants into the waters of Lake Victoria or its tributaries and adopt measures regarding introduction, monitoring, control or eliminating of such animals or plants.
30. Protocol concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region (Nairobi, 1985)	The Contracting Parties to prohibit the intentional or accidental introduction of alien species which may cause significant or harmful changes to the Eastern African region. (Article 7). To regulate any activity likely to harm or disturb the fauna or flora, including the introduction of non-indigenous animal or plant species. (Article 10).
31. Convention on Great Lakes Fisheries Between the United States and Canada (Basic Instrument for the Great Lakes Fisheries Commission - GLFC) http://www.gllfc.org/pubs/conv.htm	The Convention establishes the GLFC whose purpose is to control and eradicate the non-native, highly invasive Atlantic sea lamprey from the Great Lakes.
32. North American Free Trade Agreement (1982) http://www.sice.oas.org/tradee.asp#NAFTA	Each Party may adopt, maintain or apply any sanitary or phytosanitary measure necessary for the protection of human, animal, plant life or health in its territory (Article 712(1)). Each party shall adapt any of its sanitary or phytosanitary measures relating to the introduction, establishment or spread of an animal or plant pest or disease taking into account conditions relating to transportation and handling, between those areas. (Article 716).
33. North American Agreement on Environmental Cooperation (1993) http://www.cec.org	The Council of the Commission on Environmental Cooperation may develop recommendations regarding exotic species which may be harmful (Article 10 (2)(h)).
34. Convention for the Conservation of the Biodiversity and the Protection of Wilderness Areas in Central America (Managua, 1992)	Parties agree that all mechanisms shall be established for the control or eradication of all exotic species which threaten ecosystems, habitats and wild species. (Article 24).
35. Protocol Concerning Specially Protected Areas and Wildlife to the Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region (SPAW) (Kingston, 1990) http://www.cep.unep.org/pubs/legislation/spaw.html	Each Party shall take all appropriate measures to regulate or prohibit intentional or accidental introduction of non-indigenous or genetically altered species to the wild that may cause harmful impacts to the natural flora, fauna or other features of the Wider Caribbean Region. (Article 12)
36. IUCN-Guidelines for the Prevention of Biodiversity Loss Caused by Alien Invasive Species (2000) http://www.iucn.org/themes/ssc/pubs/policy/invasivevseng.html	Guidelines designed to increase awareness and understanding of the impact of alien species. Provides guidance for the prevention of introduction, re-introduction, and control and eradication of alien invasive species.
37. Guidelines for the Control and Management of Ships´ Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens. (Resolution A.868 (29)1997, International Maritime Organisation) http://www.imo.org	Provides guidance and strategies to minimise the risk of unwanted organisms and pathogens from ballast water and sediment discharge. Revokes the "Guidelines for preventing the Introduction of Unwanted Organisms and Pathogens from Ships' Ballast Water and Sediment Discharges" (IMO Resolution A.774 (18) 1991).
38. Recommendation No. R (84) 14 (1984) of the Committee of Ministers to the Council of Europe Member States Concerning the Introduction of Non-native Species http://www.coe.int	Recommends that Member State governments prohibit non-native species introductions into the natural environment; exceptions allowed provided study undertaken to evaluate probable consequences for wildlife and ecosystems.

Instrument/Institution	Relevant Provisions/Decisions/Resolutions
39. Agenda 21 – United Nations Conference on Environment and Development (Rio, 1992)	Calls for increasing protection of forests from disease and uncontrolled introduction of exotic plant and animal species 11.14); acknowledgement that inappropriate introduction of foreign plants and animals has contributed to biodiversity loss and continues (15.3); appropriate rules on ballast water discharge to prevent spread of non-indigenous organisms. 17.30(vi)); controlling noxious aquatic species that may destroy other aquatic species (chap. 18-40(e)(iv)).
40. Programme of Action for the Sustainable Development of Small Island States (1994) http://www.unep.ch/islands/dsidscnf.htm	Notes introduction of non-indigenous species of significant causes of biodiversity loss (Para. 41). Countries to formulate strategies at the national level for conservation and sustainable use of marine and terrestrial biodiversity including protection from non-indigenous species (Para. 45A(i)).
41. Code of Practice on the Introductions and Transfers of Marine Organisms (ICES/EIFAC 1994)	Recommends practices and procedures to diminish risks of detrimental effects from marine organism introduction and transfer, including those genetically modified. Requires ICES members to submit a prospectus to regulators, including a detailed analysis of potential environmental impacts to the aquatic ecosystem.
42. Code of Conduct for Responsible Fisheries (FAO, 1995) http://www.fao.org/fi/agreem/codecond/ficonde.asp	Encourages legal and administrative frameworks to facilitate responsible aquaculture. Including pre-introduction discussion with neighbouring states when non-indigenous stocks are to be introduced into transboundary aquatic ecosystems. Harmful effects of non-indigenous and genetically altered stocks to be minimised especially where significant potential exists for spread into other states or country of origin. Adverse genetic and disease effects to wild stock from genetic improvement and non-indigenous species to be minimised.
43. Code of Conduct for the import and release of exotic biological control agents (FAO, 1995) http://www.fao.org	Aims to facilitate the safe import, export and release of such agents by introducing procedures of an internationally acceptable level for all public and private entities involved, particularly where national legislation to regulate their use does not exist or is inadequate. Outlines specific responsibilities for authorities of an exporting country, who should ensure that relevant regulations of the importing country are followed in exports of biological control agents.
44. Preventing the Introduction of Invasive Alien Species. Resolution A-32-9, International Civil Aviation Organisation (ICAO) (1998). http://www.icao.int/icao/end/res/a32_9.htm	Urges all Contracting States to use their civil aviation authorities to assist in reducing the risk of introducing, through civil air transportation, potentially invasive species to areas outside their natural range. Requests the ICAO Council to work with other United Nations organisations to identify approaches that the ICAO might take in assisting to reduce the risk of introducing potential invasive species.
45. Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (UNEP, 1995) http://www.unep.org/unep/gpa/pol2a.htm	Introduction of Alien Species acknowledged to have serious effects upon ecosystem integrity. (para. 149).

Source: Shine, C., N. Williams, & L. Gündling (2000)
Note: Several other international and regional agreements with provisions that relate to IAS issues are not yet in force.

Annexes 2, 3, 4

Definitions of key terms

Acronyms

Phase I Products

Definitions of key terms

The following terms have been adopted for this strategy, drawing from work done under GISP Phase I. Governments have not yet adopted consistent terminology in this field, so these definitions should be considered provisional until "official" terms are adopted. At national and sub-national level, precise use of terms is very important. Definitions underpin most operational components of legal frameworks, including:

- the scope of powers and duties conferred on the competent authorities;
- the basis for listing species, excluding consignments at the border, restricting internal translocations, monitoring and implementing control strategies;
- the formulation of technical criteria to guide decision-making and risk assessments;
- the application of restrictions or incentives to particular activities or actors;
- criminal offences, which must be drafted in precise language if individual or corporate conduct is to be capable of prosecution and judgement in the courts.

Definitions therefore go to the heart of legal certainty. All actors, from quarantine personnel to shippers, traders and farmers, need to know where they stand. Consistent use of terms also helps to build awareness of invasive species problems.

Alien species (synonyms: non-native, non-indigenous, foreign, exotic): a species, subspecies, or lower taxon introduced outside its normal past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.

Biosecurity: The management of risks posed by organisms to the economy, environment and people's health through exclusion, mitigation, adaptation, control, and eradication.

Casual alien species: Alien species that may flourish and even reproduce occasionally in an area, but which do not form self-replacing populations, and which rely on repeated introductions for their persistence (Richardson et al., 2000).

Containment: keeping the IAS within regional barriers.

Eradication: the extirpation of the entire population of an alien species in a managed area; eliminating the IAS completely.

Establishment: the process of a species in a new habitat successfully reproducing at a level sufficient to ensure continued survival without infusion of new genetic material from outside the system.

GMO/LMO: A genetically-modified organism/living modified organism is one whose genetic makeup has been purposefully altered by human technology. These are addressed under Article 8(h) of the CBD.

Intentional introduction: the purposeful movement by humans of a species outside its natural range and dispersal potential (such introductions may be authorised or unauthorised) (IUCN, 2000) (c.f. unintentional introduction).

Introduction: the movement, by human agency, of a species, subspecies, or lower taxon (including any part, gametes, seeds, eggs, or propagule that might survive and subsequently reproduce) outside its natural range (past or present). This movement can be either within a country or between countries (IUCN, 2000).

Invasive alien species: an alien species whose establishment and spread threaten ecosystems, habitats or species with economic or environmental harm. These are addressed under Article 8(h) of the CBD and other instruments.

Native species (synonym: indigenous species): a species, subspecies, or lower taxon living within its natural range (past or present), including the area which it can reach and occupy using its own legs, wings, wind/water-borne or other dispersal systems, even if it is seldom found there.

Naturalized species: alien species that reproduce consistently (cf. casual alien species) and sustain populations over more than one life cycle without direct intervention by humans (or in spite of human intervention); they often reproduce freely, and d o not necessarily invade natural, semi-natural or human-made ecosystems.

Pest: "Any species, strain or bio-type of plant, animal or pathogenic agent injurious to plants or plant products" (IPPC).

Sanitary and phytosanitary measures: any measure applied a) to protect human, animal or plant life or health (within a Member's Territory) from the entry establishment or spread of pests, diseases, disease carrying organisms; b) to prevent or limit other damage (within the Member's Territory) from the entry, establishment or spread of pests.

Suppression: reducing population levels of the IAS to an acceptable threshold.

Unintentional introduction: an introduction of a species outside its natural range introduced unwittingly by humans or human delivery systems.

Weeds (synonyms: plant pests, harmful species; problem plants): Plants (not necessarily alien) that grow in sites where they are not wanted and have detectable negative economic or environmental effects; alien weeds are invasive alien species.

Acronyms

CABI	CAB International
CBD	Convention on Biological Diversity
CI	Conservation International
CITES	Convention for International Trade in Wild Fauna and Flora
FAO	Food and Agriculture Organization
GCTE	Gobal Change and Terrestrial Ecosystems
GIASIS	Global Invasive Alien Species Information System
GISP	Global Invasive Species Programme
IABIN	Interamerican Biodiversity Information Network
ICSU	International Council for Science
IGBP	International Geosphere-Biosphere Programme
IPCC	Intergovernmental Panel on Climate Change
IPPC	International Plant Protection Convention
ISSG	Invasive Species Specialist Group
IUCN	The World Conservation Union
IMO	International Maritime Organization
NASA	National Aeronautics and Space Administration
NBSAP	National Biodiversity Strategy and Action Plans
WHO	World Health Organization
WTO	World Trade Organization
WTO	World Tourism Organization
SBSTTA	Subsidiary Body for Science, Technology and Technological Advice
SCOPE	Scientific Committee for Problems of the Environment
SPS	Agreement on Sanitary and Phytosanitary Measures
WWF	World Wildlife Fund
TNC	The Nature Conservancy
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Education, Scientific and Cultural Organization

Products of GISP Phase I

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