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United States Government

Invasive Alien Species in South-Southeast Asia

National Reports & Directory of Resources

Edited by Nirmalie Pallewatta, Jamie K. Reaser, and Alexis T. Gutierrez

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Preface

This report is one of three products of a workshop entitled, *Prevention and Management of Invasive Alien Species: Forging Cooperation throughout South and Southeast Asia*. The meeting was held by the Global Invasive Species Programme (GISP) in Bangkok, Thailand on 14-16 August 2002. The other products include a workshop report, including a regional statement on IAS, available at www.gisp.org. This document is the first country-driven effort to assess the status of invasive alien species (IAS) and share information on IAS national programmes in the South-Southeast Asian region.

Each country that participated in the regional workshop was invited to submit a chapter that included information on known IAS, existing strategies for preventing and managing IAS, objectives and contact information for departments/ministeries concerned with IAS, priorities for future work on IAS, list of in-country IAS experts, and a list of relevant references and websites. Participants were asked to provide information relevant to both agriculture and environmental sectors and to work across multiple ministeries when possible. The ability of each country to provide this information varied considerably, and depended upon the amount of information already available on IAS problems in their country, existence of in-country technical expertise, and the priority attached to IAS issues by the current government. A few delegations were unable to contribute to this document and are in the process of assessing IAS status in their countries.

The data provided within this document reflects the most up-to-date information available to the authors of each country report at the time of writing. These authors and the GISP make no claims that this information is complete or scientifically accurate (e.g., scientific names may not always have been correctly assigned to non-native species), although the authors and GISP have attempted to ensure as useful and reliable a document as possible.

GISP hopes that this document will be seen as a foundation for future work on IAS within the South-Southeast Asia region. Readers who wish to provide additional information or updates to specific chapters are encouraged to contact the authors, as well as GISP. A web-based version of this report is downloadable from www.gisp.org and, if new information warrants, will be updated as appropriate.

Reports arising from GISP's workshops in other regions of the world will also be made available at www.gisp.org.

The South-Southeast Asia Region

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National Reports & Directory of Resources on IAS

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Afghanistan

No report has been submitted.

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Introduction

Bangladesh is located between 20°34' and 26°38' North and 88°01' and 92°42' East, with an area of 147,570 km^2. Geographically, the country is located at the transition of Indo-Gangetic and Indo-Malaya subregions between the Himalayas and the Bay of Bengal. Bangladesh is characterized by a sub-tropical monsoonal climate with fairly marked seasonal variations of precipitation and a mild winter from December to February. The country has 2.53 m hectares of forest land, covering 17.49% of its total landmass. Aside from ranges of hills along the Burmese and Indian borders (to the southeast and northeast), the entire country is an enormous deltaic plain flanked by the river Ganges (Padma), Brahmaputra (Jamuna), and Meghna rivers. These rivers are among the largest in the world, and along with their floodplains and tributaries that crisscross the country forming a myriad of meandering channels, lakes, ox-bows and water meadows, they form an intricate network of waterways flowing into the Bay of Bengal. Additional temporary bodies of water are formed when a large part of the country becomes submerged for 3-4 months during the monsoon season.

Bangladesh is exceptionally rich in biodiversity. The country has approximately 113 species of mammals, more than 628 species of birds, 126 species of reptiles, and 22 species of amphibians. In marine and aquatic systems, there are approximately 442 species of marine fish, 266 species of freshwater fish, 15 species of crabs, 56 species of shrimp/prawns, 362 species of mollusks, and 66 species of corals. Approximately 5000 species of angiosperms have been identified, of which 300 species are cultivated. Published records document approximately 2493 species of insects, 19 species of mites, 164 species of algae/seaweed, and 4 species of echinoderms (Alam 1967, Khan 1991, Ahmed and Ali 1996, Anonymous 2000a, 2000b). Resource managers have identified 224 species of timber-yielding plants (Mia and Haque 1986), while Khan and Mia (1984) report 130 species of indigenous fibre plants.

Numerous species are known to be threatened by various land uses and other environmental changes. These include 54 species of inland fish, 8 amphibians, 58 reptiles, 41 resident birds, and 40 mammals. Among the marine and migratory species of animals in particular, 4 fish, 5 reptiles, 6 birds, 3 mammals, and 96 seed-bearing plant species are threatened (Anonymous 2000a, 2000b).

As in many other countries of South Asia, hundreds of alien species have entered Bangladesh, intentionally and unintentionally. The remainder of this paper addresses the status of invasive alien species (IAS) in Bangladesh and what is being done to address the problem.

Invasive alien species in Bangladesh

Bangladesh has a long history of introduction of alien species of plants and animals, especially those which were found to be productive elsewhere and offered potential economic benefits to Bangladesh. Early introductions were associated with importation of exotic goods from almost every nation of Asia. Some alien species have entered the country unintentionally. For example, it is believed that many IAS were indiscriminately introduced from India with floodwaters and rapidly spread to the wetlands in Bangladesh as a sort of 'biological explosive'. Unfortunately, no consideration was made of the likely adverse effects of introduction of any alien species to Bangladesh. Quarantine measures adopted during import of alien species were weak, and as a result they were introduced into the country without proper documentation. Information such as published lists of harmful, invasive or pest alien species, and published scientific data on the ecological and economic impacts of such species, are not available. Despite the absence of studies, it is believed that a growing number of IAS are causing significant economic and environmental impacts in Bangladesh. These species include fish, insects, weeds, nematodes, crustaceans, microbial pathogens, and vascular plants. Of the hundreds of alien species introduced to Bangladesh, some have naturalized to such an extent that it is very difficult to recognize them as aliens. Some of the alien species have become invasive.

Invasive alien plants

It is very difficult to give a complete list of alien species of plants introduced into Bangladesh, as published literature is not available on this aspect. However, a list of IAS of plants introduced into Bangladesh is given in Table 2 in Appendix 1.

Invasive alien weeds

Introduction of alien species of weeds has a long history in Bangladesh. A condensed list of alien weeds with available information on country of origin, area of spread, and the damage caused by these species is presented in Table 3. Bangladesh forestry mostly uses the clear felling system which creates wide gaps that support the growth of disturbance-tolerant species, including weeds. Certain kinds of agricultural practices, including some that have been used from a long time ago, also support the growth of IAS. It has been observed that most invasive weeds grow luxuriantly at the advent of rain and continue growing until the onset of winter. Weeds prefer to grow in areas with sunlight, while the growth of most is retarded under conditions of shade leading to their eventual death. They all bear the unique character of suppressing regeneration of cultivated plants unless there is some kind of human interference.

Perhaps the first widely introduced IAS in Bangladesh is the water hyacinth, *Eichhornia crassipes*, which was brought from Brazil during the British colonial period. British ladies were fond of its attractive flowers and used them for hair-styling and decorative purposes. Now almost all the wetlands of Bangladesh are covered by this water hyacinth (Ameen, 1990), and it is a very serious invasive,

replacing indigenous aquatic species such as *Enhydra flactuans, Ipomoea aquatica* and *Dodonaea viscosa.*

Other most invasive alien weeds are: *Alternanthera philoxeroides, Argemone mexicana, Chylocalyx* sp., *Enhydra fluctuans, Mikania cordata,* and *Parthenium hysterophorus.* Though not measured scientifically, visually significant economic damage is caused by these introduced weeds. The impacts of alien species of weeds and resultant changes to local ecosystems have not yet been studied in Bangladesh. Following are brief accounts of some species of major alien weeds with their recorded impacts.

Mikania scandens, a luxuriantly growing climber which grows on wet soil with sufficient sunlight, has perennial rootstocks and rootlet climbers that grow very rapidly on the ground and also on other plants. The perennial rootstock makes it very hard to eradicate except by completely pulling it out of the ground. It is found covering entire crowns of the trees in plantations, and arrests the growth of these trees if sufficient care is not taken during establishment of the plantations. It is also a menace in the high forests. This creeper has proven itself very difficult to eradicate, and is spreading gradually into the adjacent areas of forests as well. This species most likely invaded the country after the major cyclone of the 1960s.

Sometime in the mid 1960s, *Ipomea fistula* was introduced to the coastal areas of Bangladesh. This plant accumulates salt in its tissues which does it no harm, but when it dies, the salt is released into the soil, rendering the area unfit for much of the native vegetation.

Mimosa pudica, a perennial, prickly, bristly, and creeping weed of roadsides and fallow lands, is also commonly found on the hills. It grows all over the country and is considered to have been introduced to Bangladesh more than 200 years ago. The thick layers of this species prevent growth and development of many native species including the natural germination of many valuable forest species, such as *Dipterocarpus* spp. and *Syzygium* spp., which it does by largely by preventing the seeds from reaching the soil. *Mimosa intsia,* another IAS, is found spreading in the northeastern part of the country, usually following tea cultivation.

The invasive grass *lmperata cylindrica* has overrun woodland margins in the country. This grass is highly flammable, and regenerates quickly after burning. Its most damaging impacts are hindering tree growth in plantations and virgin forests, and destruction of soil fertility by its greater adaptability to dry open areas. It is very difficult to eradicate this from plantations, since it is gregarious in nature, with a strongly spreading root system.

Some other alien weeds are listed below:

Cleome hassleriana is growing dominantly in marshy areas of the northeastern part of the country, where it was introduced as long ago as 200 years or so, following tea cultivation.

Croton bonplandianus is a common branched perennial herb with watery juices. Known as a common weed of road sides and waste lands of the eastern part of the country, this plant was introduced from Brazil during the 1890s.

Croton lobata, a perennial under-shrub, is a weed of wastelands and roadsides mostly found in the eastern part of Bangladesh. The plant has been growing in this region since 1940s.

Panicum repens, another aggressive grass, is found invariably in the coastal region of Bangladesh, and was introduced over a hundred years ago.

Lantana camara var. *aculata,* which is prickly and difficult to pull out, grows mostly in the hilly regions. This species was introduced to Bangladesh around 200 years ago. A scrambler, it is a menace to the seedlings used for artificial regeneration in forest areas.

Chromolaena (Eupatorium) odorata, introduced in the mid 1940s, is a coarse straggling under-shrub species, growing as a bush. It has displaced virtually all other vegetation from some places in the hill regions. This species is more destructive whenever vegetation clearing is done. Unless quick remedial measures are taken, the area becomes covered with this invasive within a period of about three years, forming an impenetrable thicket.

Ageratum conyzoides (introduced to Bangladesh during the 1940s) does great damage by precluding natural regeneration, covering crowns of trees, and killing the foliage of existing crops.

Opuntia dillenii, a well-known cactus invasive and a native of South America, was introduced to coastal Bangladesh some time in the past.

Parthenium sp. (*hysterophorus?*) is present in Bangladesh for the past 15 years, and is known to cause serious allergic reactions to its pollen.

Alien plants grown for forestry

Valuable timber species such as teak *(Tectona grandis),* mahogony *(Swietenia mahogonii* or *S. macrophylla),* and fast growing alien tree species such as *Eucalyptus camaldulensis, Acacia mangium, Acacia auriculiformis* and *Leucaena leucocephala,* have been introduced for development of forestry. Some of them are now well acclimatized to the country. Several species from the two genera, *Acacia* and *Eucalyptus* from Australia and eastern Malaysia, have been introduced into Bangladesh, mostly during the 1980s. Plantations of fast growing eucalypts, *A. auriculiformis* and *A. mangium* from Australia, are a common choice for pulp and fuelwood in Bangladesh. All these species have proven to be rivals to endemic flora, eventually replacing indigenous forest species as well as other native wild flora. For example, *A. auriculiformis* germinates naturally in plantation forests and forms congested seedling areas which in turn prevent natural germination of some native forest species.

Acacia and *Eucalyptus* trees produce leaves that are not easily degradable, and thus the soil becomes less fertile, threatening the existence of thousands of humus-dependent species including herbs and earthworms. These trees are said to absorb large amount of water and nutrients from the soil rather rapidly, and hence even the indigenous trees cannot properly grow around it. Some species of eucalyptus are therefore used for draining swamps. Furthermore, birds are observed to avoid eucalyptus plants. These trees do not support wildlife because they do not produce edible fruit or nectar for them. The monocultures of these species are lifeless, and the tall and slender stems of these species are not storm tolerant and cannot shelter any fauna during storms. Moreover, the spores produced by the flowers of these trees create allergic diseases in the respiratory tracts of human beings (Ameen, 1999).

There are many other alien species growing in Bangladesh, such as oil palm (*Elaeis guinensis),* rubber *(Hevea braziliensis)* (introduced in 1964 and 1910 respectively), and *Pinus caribeae* and *Pinus oocarpa,* introduced in 1940 and 1970 respectively. However, we still do not have any assessment of the impact of these species on native biodiversity and gene pools. So far, only growth and spacing trials of alien forest species have been carried out. During introduction of alien species, only quarantine regulations for exclusion of insect pests intimately associated with timber, along with fungi and bacterial pathogens, are followed.

Alien ornamental plants

Ornamental plants such as Krishnachura *(Poinciana pulcherrima),* Radhachura *(Delonix regia),* and *Peltophorum ferrugineum,* and various types of cacti and orchids, have entered the country. Yet again, we have no comprehensive assessment of the impacts and status of spread of these species.

Invasive alien fish

Among the animal species, the recent introductions are mostly fish. Due to increased demand for fish resources (fish being one of the major sources of protein), caused by the human population explosion, fish species capable of producing a higher biomass in a shorter period than native species were introduced. About 15 alien species of fish, mostly carps, were introduced to Bangladesh. A list of different alien species of fish introduced into Bangladesh is given in Table 1. The main objectives of these introductions were: augmenting fish production, use of some as predators of pest insects and weeds, and some for use in aquaria and decoration. Hardly any studies on the influence of the imported species and their interactions with local species and the natural environment preceded these introductions.

Some of the introduced species have been found to be competing with local species for food, to the detriment of the latter. The most disastrous invasive alien fish species are *Clarias gariepinus* (native of Africa), *Pangasius sutchi, P. giganticus* (naturally occurring in Southeast Asia), *Tilapia mossambica* and *Tilapia nilotica*. These fish species were brought from Thailand between 1953 and 1990 (Rahman, 1997). The predatory habits of the first three species are well known and legendary. *Clarias gariepinus* and *Pangasius* spp. eat almost everything they encounter. They not only feed on indigenous fish species and domestic ducklings, but also on snails and birds that are killed and supplied by cultivators. As a result, the vulture population of the country is also threatened, because carcasses that would have been available to them are collected and supplied to these fish species (Rahman, 1997). The last two species are not predatory species, but their fecundity and growth rate are very high, and they can breed naturally. *T. mossambica* and *T. nilotica* are competing with small native fish species, and gradually occupying their niches. In case of carps, some interesting research data have been collected. The local major carps contributed 67% of the total stock in 1967 in Sylhet-Mymensingh haor (large marshland) basin, but rapidly declined to 50% in 1973 and only managed a 4% contribution in 1984 (Tsai and Ali, 1987).

The following are a few more examples of introductions:

- Grass Carp *(Ctenopharyngodon idella)* introduced to Bangladesh from Hong Kong in 1966;
- Silver Carp *(Hypopthalmichthys molitrix)* naturally occurring in China was introduced to Bangladesh from Hong Kong in 1969;
- The Goldfish *(Carassius auratus)* was brought from Pakistan in 1952 and is used as decorative species in aquaria and cement tanks.

Many IAS were indiscriminately introduced, and rapidly spread to wetlands as a kind of 'biological explosion' along with floodwaters from India. Some of the introduced fish species were recommended only for restricted cultivation in closed ponds, but these plans were unsuccessful as closed ponds could not be maintained due to floods. The result is that 54 indigenous fish species have become threatened within a very short time, and many of them will become extinct from Bangladesh if this process continues (Islam et al., 2000).

Fish diseases

Epizootic Ulcerative Syndrome has been causing large-scale fish mortality in the floodplains. The occurrence of Epizootic Ulcerative Syndrome disease was first reported in February 1988 from Chandpur. Ali (1991) reported that the disease broke out almost all over Bangladesh causing heavy mortalities of native fish such as Snakeheads ('taki,''shol'), eel ('baim'), perches ('Koi,' 'Kholisha,''meni'), barbs ('punti'), and gobies ('bele'). Major species of local carps and their fingerlings in floodplains and ponds were also affected. Minkin (1988) suspected that this disease possibly entered Bangladesh through the introduction of alien fish, *Puntius gonionotus*, a carrier of the infective agent to Bangladesh. This disease has been reported from Thailand, Philippines, Myanmar, Sri Lanka, Malaysia and Laos (Minkin, 1988). The Fisheries Specialist Study in Bangladesh's 6th Flood Action Plan (FAP6, 1993) reiterates the suspicion that the disease was introduced into the country through imported alien species, and indicates that this fish disease has played an important role in reducing fish production in Bangladesh.

Invasive alien insect species

The Spiralling Whitefly (*Aleurodicus dispersus*) is a serious pest of guava, *Capsicum* spp., and a number of ornamental plants. This insect pest may also infest mango leaves. This insect has not been reported in published literature even up to the 1980s as a pest of guava or any other economic plant, from India, Pakistan and Bangladesh, but serious infestations of this insect pest have been found in guava and some ornamental plants (including 'Madhabi Lata') in Dhaka city since the early part of 1993. The Spiralling Whitefly is now a major pest of guava in most parts of the country. It is suspected that this pest species was introduced in Bangladesh through hand-carried and unchecked plant materials from other countries (Karim, 1995). The introduced multipurpose tree *Leucaena leucocephala* in Bangladesh is not free from its major pest, the psyllid bug *Heteropsylla cubana* (?) (personal communication from Karim, M.A., 2002). There is no published literature on other invasive alien insect species in Bangladesh. Absence of insect taxonomic identification services in Bangladesh is a major limiting factor in reporting any new invasive alien insects. Much more work has to be carried out on the status, and impacts of invasive alien insect species on ecosystems of Bangladesh.

Management of IAS

The following sections will provide a brief outline of the issues and options for management of biodiversity that have relevance to the topic of IAS.

Legal instruments

Following are the legal instruments of Bangladesh for management of its biodiversity, which also relate to prevention of introduction of alien organisms:

- Destructive Insects and Pest Act of 1914;
- Forest Act of 1927;
- Bangladesh Wildlife (Preservation) (Amendment) Act of 1974;

In addition, Bangladesh is signatory to the:

- International Plant Protection Convention (in 1974);
- Convention on Biological Diversity, CBD (in 1992);
- Agreement on the Network of Aquaculture Centres in Asia and the Pacific (in 1990);
- UN Framework Convention on Climate Change (in 1992);

- Ramsar Convention (in 1992);
- Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) (in 1981);
- Global Tiger Forum (in 1999).

Bangladesh, as a signatory to the CBD, has already initiated plans and programmes to fulfill its obligations to the convention. Biodiversity resources are under the management of several government agencies. They are all agencies that have the potential to manage IAS, and are listed later in this paper.

The Forest Department manages 1.53 m ha forestland, approximately 10.54% of the total land area of the country. Of Bangladesh's total forested area, 0.24 million ha constitutes protected areas. Government policy is to manage its forests under two categories: productive forests and protective forests, to meet the demand for forest produce and to conserve the threatened biodiversity of the country respectively. The government of Bangladesh imposed a restriction on all tree felling in the Natural Reserve Forests until the year 2005.

Since wetlands abound with biological diversity, and since Bangladesh is a Contracting Party to the Ramsar Convention, necessary steps are being taken to conserve aquatic ecosystems as Bird, Fish and Wildlife Reserves. It is obvious that besides this measure, that some sort of monitoring programme should be undertaken in wetlands to prevent and control the introduction of alien fish species.

Quarantine

The existing plant quarantine legislation, known as Destructive Insects and Pest Rules, 1966 (Plant Quarantine), were framed as per provisions of sub-section (1) of Section 3, Section 4A and 4D of the Destructive Insect and Pest Act, of 1914. The director, Plant Protection Wing of the Department of Agricultural Extension under the Ministry of Agriculture, is responsible for execution and implementation of the plant quarantine legislation. Fifteen plant quarantine stations are functional at various entry points to Bangladesh. The country became a member of the Asia and Pacific Plant Protection Commission in 1978.

Bangladesh and India signed a bilateral Memorandum of Understanding on quarantine issues in 1978. The Department of Livestock under the Ministry of Fisheries and Livestock executes the animal quarantine legislation.

On average, 1.5 million tons of plants and plant products are imported in Bangladesh every year from different countries, under plant quarantine inspection. On the other hand, about 0.4 million tons of agricultural commodities, mainly raw jute and jute products, handicrafts, vegetables, and fruits are inspected for issuing phytosanitary certificates, for the purpose of export.

A total of 2,006 fruit and flower saplings were destroyed at entry points from 1999 to 30 June, 2002 due to detection of harmful nematodes. Most of these saplings were brought from Mozambique, Ghana, Papua New Guinea, Afghanistan, UAE, Russia, Kenya, Uganda, Portugal and Poland. The detected nematode species were *Ditylenchus dipssci, Radopholus similis, Creconema* sp. and *Xiphenema* sp. One consignment of 50 metric tons of imported seed potato (*Solanum tuberosum*), from the Netherlands was intercepted and destroyed due to presence of *Erwinia atroseptica* and *Ralstonia solanacearum* infection in 1999, although the consignment of seed potatoes was accompanied by a valid phytosanitary certificate issued by the NPPO of the Netherlands. Another consignment of 1000 metric tons of tuber potatoes for consumption, imported from India in 1999, was refused entry to Bangladesh for reason of contamination with cysts of *Globodera rostochiensis* (Bulbul, 2000).

Pest management policy

Integrated Pest Management (IPM) activities, started in 1981, have already passed through several phases of research and extension. It has made an immense contribution to the reduction of pesticides in crop production. Results show that it has the potential to increase crop production directly, with little or no adverse effects on agro-ecosystems. Considering these benefits of IPM, the government has initiated the National Integrated Pest Management Policy in 2002.

Public awareness and education

In Bangladesh, the general public is not aware of the harm caused by IAS, their potential future risks to local ecosystems and its exceptionally rich biological heritage. There are very few publications or guidelines on IAS available in Bangladesh. The need for education extends over many sectors such as policy makers, researchers, extension personnel, administrators, politicians, farmers and the general public. Messages on IAS should be spread, using various media such as booklets, newspapers, radio, and television. People should be motivated to cultivate indigenous species. Both positive and negative impacts of IAS on native ecosystem need to be introduced at school, college and university level curricula, which will help create awareness among the future generation of decision makers, about the impacts of IAS, their prevention and establishment.

List of government agencies that have the potential to manage IAS

1. Forest Department
2. Department of Environment
3. Department of Agricultural Extension
4. Department of Fisheries
5. Department of Livestock
6. Bangladesh Forest Research Institute (BFRI)
7. Fisheries Research Institute (FRI)
8. Bangladesh Rice Research Institute (BRRI)
9. Bangladesh Agricultural Research Institute (BARI)
10. Bangladesh Jute Research Institute (BJRI)
11. Bangladesh Tea Research Institute
12. Bangladesh Cotton Development Board
13. Sugarcane Research Institute
14. Sericulture Research Institute
15. Livestock Research Institute
16. Wheat Research Institute
17. National Herbarium
18. Botanical Garden
19. Zoological Gardens
20. Mango Research Institute
21. Tourism Department
22. Customs Department
23. Seed Certification Agency
24. Bangladesh Water Development Board
25. Barind Multipurpose Development Authority

Experts associated with direct management of IAS

1. Member-Director (Crops), Bangladesh Agricultural Research Council, Ministry of Agriculture, Farmgate, Dhaka-1215, Bangladesh.
2. Director, Plant Protection Wing, Department of Agricultural Extension, Ministry of Agriculture, Khamarbari, Dhaka-1215, Bangladesh.
3. Director General, Department of Livestock, Ministry of Fisheries and Livestock, Farmgate, Dhaka-1215, Bangladesh.
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6. Director, Bangladesh Forest Research Institute, Chittagong, Bangladesh.

Future steps

The study of IAS is a completely new issue in Bangladesh. Information on IAS is therefore very scanty and not gathered systematically. A thorough study of IAS must be carried out and should consist of:

- Inventory and identification of IAS;
- Description of the natural habitat and geographic origin of each alien species, its habitat, and role in the environment;
- Mechanisms by which these organisms survive, propagate and spread;
- Establishment of clear quarantine regulations on IAS, and assessments of their effectiveness;
- International co-operation in information exchange, and on experiences gained with relevant IAS;
- Prior clearance for species of economic and/or aesthetic importance before introduction to a country, with documentation of country of origin, concerned organizations, and probable ecological impact on the native species;
- Development of standardized procedures for introduction and monitoring of species;
- Political commitment through promulgation and enactment of proper legal instruments.

Conclusions

The IAS issue needs to be put on the national agenda in Bangladesh, and action should be taken now. Not taking action will result in substantial economic loss and damage to ecosystems and the rich biological heritage of Bangladesh. The status and impacts of existing IAS (especially intentionally introduced species) in different regions of Bangladesh must be studied. These studies will improve public awareness of the impact of alien species to the national economy and ecosystems.

For economic reasons, and the need for development of resources, it is essential sometimes to introduce alien species in forestry, agriculture and fisheries, but care should be taken about their nature and potential impacts. A species should only be introduced after risk assessment and environmental impact

assessments. Adequate quarantine regulations should be promulgated to include the control of IAS introductions and establishment, in particular the inspection of vessels and other containers that may carry propagules. No predatory species should be introduced.

Combating IAS in Bangladesh will be very difficult because of the absence of lists of identified IAS, properly carried out case studies on economic and ecological impacts, programmes on management efforts, awareness campaigns, coordination among different ministries and agencies and priorities for future work. As IAS require an integrated approach, all relevant departments should be integrated in their approaches to address IAS by the establishment of a **national focal point,** and by monitoring and implementation of legal instruments. In this context, Bangladesh needs international cooperation in developing, sharing, linking and integrating IAS databases and information systems, and research support for effective prevention and management of IAS.

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APPENDIX 1

Table 1. List of IAS of fish introduced in Bangladesh

Name of species	Common name	Natural habitat	Country of origin	Year of introduction
Trichogaster pectoralis	Siamese Gourami	Thailand	Singapore	1952 *
Carassius auratus	Goldfish	Europe, Asia	Pakistan	1953 ***
Tilapia mossambica	Tilapia	Africa	Thailand	1954 *
Lebistes reticulatus	Guppy	S. America	Thailand	1957 ****
Cyprinus carpio var. *communis*	Common Carp/Scale Carp	Temperate Asia, Europe	Not known	1960 1965 ****
Ctenopharyngodon idella	Grass Carp	China	Hong Kong Japan Nepal	1966 1970 1979 **
Hypopthalmichthys molitrix	Silver Carp	China	Hong Kong Japan	1969 1970 ****
Tilapia nilotica	Nilotica	Africa	Thailand	1975 *
Puntius gonionotus	Thai Sarpunti/ Rajpunti	Indonesia, Thailand, Malaysia, Philippines	Thailand	1986 ****
Cyprinus carpio var. *specularis*	Mirror Carp	Temperate Asia, Europe	Nepal	1979 ****
Aristichthys nobilis	Bighead Carp	China	Nepal	1981 ****

Mylopharyngodon piceus	Black Carp/ Snail Carp	China	China	1983 ****
Clarias gariepinus	African Magur	Africa	Thailand	1989 ****
Pangasius sutchi	Pangas	Thailand, Indochina	Thailand	1990 ****
Pangasius giganticus	Giant Pangas	unknown	unknown	unknown

Source: Department of Fisheries 2001, Matshya Bhaban, 13 Shaid Munsur Ali Sharani, Ramna, Dhaka-1000.

** Insect control and experimental cultural purposes, ** Weed control & experimental cultural purposes, *** Aquarium & decoration purpose & **** Experimental or cultural purposes.*

Table 2. List of IAS of plants introduced in Bangladesh

Name of species	Common name	Natural habitat
Acacia auriculiformis	Akashmoni	Papua New Guinea, Australia, Torres Strait Island
Acacia mangium	Mangium	Australia, Papua New Guinea, Indonesia
Paraserianthes (Albizia) falcataria	Malacana	Papua New Guinea, Solomon Island, The Moluccas
Dalbergia sissoo	Sissoo	Indian subcontinent
Eucalyptus brassiana	Eucalyptus	Papua New Guinea, Australia
Eucalyptus camaldulensis	Eucalyptus	Throughout the Mediterranean
Eucalyptus tereticornis	Eucalyptus	Australia
Leucaena leucocephala	Telekadam/ Epilepil	Mexico, North Central America
Pinus caribaea	Caribaea pine	Nicaragua, Guatemala, Bahamas
Pinus oocarpa	Pine	Nicaragua Mexico, Guatemala, Honduras, El Salvador
Swietenia macrophylla	Mahogany	Central and South America
Swietenia mahogani	True mahogany	North America, Cuba, Bahamas
Tectona grandis	Teak	South-east Asia
Xylia dolabriformis	Pynkado	Myanmar, India

Source: Zabala, 1990.

Table 3. List of IAS of weeds introduced in Bangladesh

Name of species	Common name (Bengali name), family	Country of origin and natural habitat	Harmful effect
Alternanthera philoxeroides	alligator weed (Helencha) Amaranthaceous	Brazil	Weed of transplanted and deep water, in Aman, Boro and Aus rice fields, grows in shallow and stagnant water, ditches and ponds.
Argemone mexicana	Mexican poppy (Shialkata) Papaveraceae	Tropical America and Mexico	Aggressive weed, reduces plant diversity. Grows in wheat, sugar-ane, potato, pulses and tea fields.
Chylocalyx sp.	Not known Polygonaceae	India	Forms mats over other plants including crops (wheat, mustard), climbs several metres onto trees. Major agricultural pest.
Croton bonplandianus	Not known (Banmoricha) Euphorbiaceae	South America	Grows widely, competes with crops (corn, sugarcane, pulses).

Name of species	Common name (Bengali name), family	Country of origin and natural habitat	Harmful effect
Cyperus alternifolius	Mistletoe Cyperaceae	Tropical Africa and Arabia	Grows in paddy fields.
Cyperus exaltatus .	(Muthagrass) Cyperaceae	Tropical Africa	Grows in paddy fields.
Dendropthe falcata ? (untraceable species- ed.)	Not known (Furulla/Bantha) Loranthaceae	India to Tropical Australia	Parasitic plant can kill the host plants.
Eichhornia crassipes	water hyacinth (Kachuripana) Pontederiaceae	Brazil	Blocks waterways, damages paddy fields, creates mosquito habitat.
Eleocharis dulcis	Not known Cyperaceae	Tropics	Grows profusely in stagnant and slow moving water.
Enhydra fluctuans	Harkuch (Hinchashak) Compositae	Malaysia	Problem in Aus, Aman, Boro rice, Jute and Rabi fields. Profuse growth prohibits light penetration, depleting oxygen from wetlands.
Hibiscus tiliaceus	Not known (Bhula) Malvaceae	Tropics of both Hemispheres	Grows vigorously, smothers other species, makes forests and other places inaccessible to humans.
Hydrolea zeylanica	Not known (Bishlanguli) Hydrophyllaceae	Tropical America and Africa	Grows in marshy places. It is also grown in irrigated rice fields.
Ipomoea aquatica	Morning glory (Kalmi) Convolvulaceae	Tropical Africa	Dense growth covers water body and may cause oxygen depletion. Grows in Aus rice and Jute fields.
Macrosolen cochinchinensis	Not known Loranthaceae	China	Parasitic plant may kill the host.
Mikania cordata	Mikanialata (Assamlata) Compositae	Tropical America	Serious weed of tea, rubber and forest crops.
Parthenium hysterophorus	Not known Compositae	Tropical America, West Indies (Jamaica)	Poisonous, causing skin eruptions in animals. Very harmful for cattle in the dry season. Grows widely and competes with crops. Poisonous to fish.
Sagittaria sagittifolia	Common arrowhead (Sota Kut) Alismataceae	North America and Europe	It grows in shallow water, ditches and lowlands. It is a problem in deep water Aman rice fields.
Pistia stratiotes	Water lettuce (Tupapana) Araceae	Tropical	It grown in irrigated rice fields and in fishponds. Covers water surface and causes depletion of oxygen in water.

Source: Islam, 1985 and Karim and Kabir, 1995, personal communication.

Bhutan

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Overview

Bhutan forms part of the Eastern Himalayan biological hotspot and has 72% of its land still under forest, containing exceptionally high levels of biodiversity. In recognition of the need to preserve its natural heritage, the Royal Government of Bhutan has declared 26% of the country as protected areas. In its efforts to maintain the pristine state of its ecosystems, management of IAS becomes highly relevant and urgent for Bhutan.

In addition to the increasing threat posed by IAS, the country at present has only limited professional management capability in this field. Available evidence indicates that Bhutan's environment so far has not seen many IAS, either introduced deliberately, or unintentionally outside their natural habitats. However, environmental and socio-economic impacts of harmful IAS are already being felt, especially by Bhutanese farmers.

The Ministry of Agriculture oversees the management of all IAS in the country and has established a Quality Control and Regulatory Services (QCRS) department which addresses IAS, among other issues. There have been several research and extension programmes, but Bhutan yet has no systematic plan and strategy on IAS. Some of the priorities for Bhutan on this subject would include: formulation of guidelines for the prevention of biodiversity loss caused by IAS, design of legal and institutional frameworks on IAS introductions and their control, training, and development of collaborative programmes with countries in the region on control and management of IAS.

Introduction

Hidden deep in the folds of the great Himalaya Mountains for years, Bhutan developed its own unique civilization. In this country, the population consisting of about 600,000 people lives in close harmony with nature and have evolved a unique identity derived largely from a rich religious and cultural heritage. Today, the world sees many exotic aspects of this kingdom. While the world mourns the loss of its natural wealth, this small Himalayan Kingdom is emerging as an example to the international community, with more than 72 percent of its land still under forest and containing a great variety of rare plant and wildlife species.

Bhutan has high biodiversity and forms part of the Eastern Himalayan biological hotspot. Preliminary surveys have shown that Bhutan has more than 7000 species of vascular plants, 700 birds, 165 mammals, 200 fungi, while many more species are being discovered at every new field survey. One of reasons attributed for this high level of biodiversity is the location of the country- a place where two biological realms meet, i.e. the Palearctic from the north and Indo-Malayan from the south. Moreover, the country's elevation ranges from 150 meters above mean sea level in the south, to over 7000 meters in the north, which accordingly has ecosystems ranging from sub-tropical to alpine in nature.

To ensure that biodiversity continues to receive adequate attention of the Royal Government of Bhutan, 26% of the country has been declared as protected areas representing all the ecosystems. Biological invasions operate now on a global scale, and will undergo rapid increase in this century due to interaction with other global changes, such as increasing globalization of markets, explosive rises in global trade, travel, tourism and exchange of goods. Therefore, management of IAS becomes even more relevant and urgent for Bhutan in its efforts to maintain the pristine state of its ecosystems. In addition, at present the country has only limited professional management capability in this field.

Alien species identified as harmful, invasive or pests, and their ecological and economic impact

Available evidence indicates that Bhutan's environment so far has not seen many IAS, either introduced deliberately, or unintentionally outside their natural habitats, where they have the ability to establish themselves, invade, out-compete native species and takeover the new environments. However, environmental and socio-economic impacts of harmful IAS are already being felt to some degree in Bhutan as well. For example, Bhutanese rice farmers are losing crops to the invasive alien waterweeds such as *Potamogeton distinctus*. Terrestrial weeds like *Lantana camera*, *Parthenium* spp., and *Mikania micrantha* are invading the Bhutanese forests, just as they have proven themselves to be problems the world over. Alien invasive plant diseases like chilli blight caused by *Phytophthora capsici*, rice blast caused by *Pyricularia oryzae*, and potato late blight caused by *Phytophthora infestans* are nuisances to Bhutanese farmers and cause heavy crop losses.

Existing IAS programmes at national level

⇒ *Quality Control and Regulatory Services (QCRS)*

The QCRS Department has been established under the Ministry of Agriculture (MoA), Royal Government of Bhutan. The Department is entrusted to inspect all plant species that are intended to be imported to the country. Its mandate is as follows:

- Improve the quality of goods and products related to the Ministry of Agriculture and its clients;
- Regulate the quality of products both locally produced and imported for the domestic market in accordance with set standards;
- Regulate the quality of products both locally produced or imported for further processing for export, in accordance with set standards;
- Ensure available food in the market is of good quality and safe for human consumption by checking for adulteration, contamination, pesticide residue levels, heavy metal contamination and general hygiene in collaboration with other relevant organizations;
- Check the flow of diseases and pests pertaining to food and agricultural crops and livestock to prevent introduction of pests and diseases that are not in the country or widespread in the country;
- Extend cooperation in controlling/ preventing the movement of pests and diseases in international trade and traffic;
- Implement acts and by-laws of the Royal Government of Bhutan related to the renewable natural resources sector, such as the Livestock Act, Seeds Act, Pesticide Act and Quarantine Act, and initiate amendments wherever necessary;
- Coordinate quality control and regulatory activities together with domestic and international organizations;
- Ensure that the quality of agricultural and livestock products meets minimum standards as given by the relevant organizations; and
- Act as a National Food Inspectorate.

⇒ *Protected area management*

The management plans of protected areas prohibit the introduction of any IAS into the protected areas, and heavy penalties are imposed for defaulters. Before introducing any new species in to protected areas, the species has to be thoroughly screened and tested for its potential negative impacts on the ecology or on economic local plants.

⇒ *Afforestation Programme*

Introduction of exotics is highly regulated in this programme, particularly those that may be associated with alien IAS. For instance, no earth attached to the plant can be imported.

⇒ *Research and extension programmes*

- *Parthenium* weed control campaign and literature reviews for *Parthenium* weed.
- Participatory trials on chili blight (*Phytophthora capsici*) control by fungicides are carried out in various districts. One replication of the chili blight trial is maintained in a research farm to check for the effects of altitude, if any.
- Control campaign for *Potamegeton distinctus*, a noxious, perennial, aquatic weed infesting wetlands. Activities were training of farmers, study tours and awareness creation.
- The MoA is gearing up for an awareness campaign on *Lantana camara* management and mitigation.
- Forecasting and management of late blight in potato.
- Forecasting and management of rice blast in paddy

Government agencies, ministries and non-governmental organizations involved in IAS management

The Ministry of Agriculture, Royal Government of Bhutan oversees the management of all IAS in the country. It deals with all policy matters and communicates with agencies within and outside the country. At the operational level, the following agencies are entrusted with the responsibility of ensuring that IAS are not introduced into the country and propagated. Personnel from all the three departments are posted at all entry points of the country, both land and air.

- Quality Control and Regulatory Services
- Department of Forestry Services
- Department Revenue and Customs, Ministry of Finance.

For management of introduced species, the MoA entrusts this responsibility to its three main departments:

- Department of Research and Development Services
- Department of Forestry Services
- Department of Agriculture and Livestock Support Services.

The other main agency which is involved directly or indirectly is:

- National Biodiversity Centre, Ministry of Agriculture.

Priorities for future work and strategies for management of IAS

There is an urgent need to address the impact of IAS in the world. Eradication, control, mitigation of their impacts, and legislation and guidelines at national and regional levels would be some of the ways forward. In Bhutan yet there is no systematic plan, nor detailed strategies for addressing this issue.

Some of the priorities for Bhutan on IAS would be:

- Formulation of guidelines for the prevention of biodiversity loss caused by IAS;
- Design of legal and institutional frameworks on IAS introductions and control;
- Training adequate numbers of professionals who are capable of identifying, and managing IAS. The country currently has only a limited number of trained people in the management of IAS;
- Establishment of separate units within the various government agencies to operate management plans for IAS. This would require both hard and soft infrastructure such as office buildings, database facilities, field equipment, communication systems, etc.
- Development of collaborative programmes with countries in the region on control and management of IAS. Research would be another area of interest, as well as being useful for long-term planning of IAS management.

List of experts working in the field

Experts and scientists from various departments within the Ministry of Agriculture are working to prevent/delay the introduction of IAS and on their management. They are in the following divisions:

- Quality Control and Regulatory Services, Ministry of Agriculture
- Nature Conservation Division, Department of Forestry Services, Ministry of Agriculture
- Renewable Natural Resources -- Research Centers, Department of Research and Development Services, Ministry of Agriculture

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List of alien species that been identified as harmful, invasive or pests and their impacts

Brunei Darussalam, through its Department of Agriculture (DoA), conducted a survey of plant diseases from January 1996 to December 1998. During the survey, a total of 101 new diseases were recorded (new to Brunei Darussalam). This list of diseases and pathogens is attached in Table 1 of this paper. Of the total of 101 disease records, there were 36 new diseases of fruit crops, 10 of vegetables, 45 of ornamental plants and 10 of miscellaneous crops and medicinal plants. No cases of pests and disease are yet reported of significant ecological or economic impacts in Brunei Darussalam.

Table 1. List of new diseases recorded in Brunei Darussalam (1996-1998)

A.	**Fruit crops**			
Local name		**Common name**	**Disease**	**Pathogen**
1.	durian putih	durian	patch canker	*Phytophthora palmivora*
2.	durian putih	durian	leaf blight	*Phytophthora palmivora*
3.	durian kuning	durian kuning	fruit rot	*Geotrichum candidum*
4.	durian kuning	durian kuning	fruit rot	*Colletotrichum gloesporoides*
5.	durian pulu	durian pulu	fruit rot	*Gliocephalotrichum bulbilium*
6.	durian pulu	durian pulu	fruit rot	*Cylindrocladium scoparium*
7.	durian putih	durian	leaf anthracnose	*Colletotrichum gloeosporioides*
8.	pisang	banana	blackcross leaf spot	*Phytophthora musicola*
9.	pisang	banana	black sigatoka	*Pseudocercospora fijiensis*
10.	pisang	banana	leaf spot	*Periconiella musae* ?
11.	pisang	banana	rust	*Uromyces musae*
12.	pisang	banana	leaf speak	*Zygophiala jamaicensis* ?
13.	limau manis	sweet orange	bacterial canker	*Xanthomonas campestris pv citri*
14.	limau manis	sweet orange	sooty mold	*Chaetobolisia* sp. ?
15.	limau manis	sweet orange	sooty mold	*Trispospermum* sp.
16.	limau manis	sweet orange	stem rot	*Phytophthora citricola*
17.	limau kasturi	musklime	black mildew	*Meliola citricola* ?
18.	mangga	mango	crusty leaf spot	*Zimmermaniella trispora* ?
19.	kepayas	papaya	powdery leaf spot	*Oidium caricae-papaya*
20.	manggis	mangosteen	flower blight	*Rhizopus oryzae*
21.	manggis	mangosteen	seed rot	*Aspergillus niger*
22.	tarap	tarap	fruit rot	*Botryodiplodia theobromae*
23.	tarap	tarap	seed rot	*Pestalotiopsis* sp.
24.	tarap	tarap	seeding blight	*Botryosporium longibrachiatum* ?
25.	ciku	sapota	sooty mold	*Polychaeton* sp.

26.	kepayang	kepayang	leaf spot	*Pseudocercospora pangiicola*
27.	longan	longan	fruit rot	*Botryodiplodia*
28.	longan	longan	fruit rot	*Geotrichum candidum*
29.	longan	longan	sooty mold	*Polychaeton* sp.
30.	longan	longan	fruit rot	*Colletotrichum gloeosporiodies*
31.	sekoi	water melon	wilt	*Fusarium oxysporum*
32.	rambutan	rambutan	fruit rot	*Colletotrichum gloeosporiodies*
33.	kelapa	coconut	leaf spot	*Fusarium oxysporum*
34.	kelapa	coconut	leaf spot	*Periconiella cocos*
35.	buah delima	pomegrante	leaf spot	*Phyllosticta* sp.
36.	jambu air	bell fruit	fruit anthracnose	*Colletotrichum gloeosporiodies*

B.	**Vegetable crops**			
Local name		**Common name**	**Disease**	**Pathogen**
37.	kacang panjang	longbean	stem blight	*Diplodia* sp.
38.	kacang bindir	okra	leaf spot	*Cercospora malayensis*
39.	kacang bindir	okra	anthracnose	*Colletotrichum capsici*
40.	lobak putih	radish	leaf spot	*Alternaria brassicicola*
41.	labu kuning	pumpkin	leaf spot	*Corynespora cassiicola*
42.	petola	bottle gourd	fruit rot	*Botryodiplodia theobromae*
43.	petola	bollte gourd	fruit rot	*Monilinia fruticola*
44.	peria	bitter gourd	leaf spot	*Cercospora cocciniae*
45.	pengaga	pengaga	leaf spot	*Cercospora apii*
46.	lobak merah	carrot	tuber rot	*Chalaropsis thielavioides* ?

C.	**Ornamental crops**			
Local name		**Common name**	**Disease**	**Pathogen**
47.	anggerek	orchid	collar rot	*Sclerotium rolfsii*
48.	anggerek	orchid	leaf spot	*Stenella orchidacearum*
49.	anggerek	orchid	leaf spot	*Leptosphaerulina trifolii* ?
50.	anggerek	orchid	leaf spot	*Phomopsis* sp.
51.	anggerek	orchid	leaf spot	*Mycoleptodiscus indicus*
52.	anggerek	orchid	leaf spot	*Diplodia* sp.
53.	bunga kertas	bougainvillea	fungal leaf spot	*Passalora bougainvilleae*
54.	bunga kertas	bougainvillea	bacterial leaf spot	*Pseudomonas andropogonis*
55.	bunga kertas	bougainvillea	leaf spot	*Phomopsis* sp.
56.	bunga matahari	sunflower	powdery mildew	*Oidium* sp.
57.	anthurium	anthurium	bacterial leaf spot	*Xanthomonas campestris* pv. *dieffenbachiae*
58.	caladium	caladium	leaf spot	*Passalora caladii*
59.	alocasia	alocasia	leaf spot	*Stenella* sp.
60.	dieffenbachia	dieffenbachia	anthracnose	*Colletotrichum gloeosporioides*
61.	dracaena	dracaena	leaf spot	*Stenella* sp.
62.	syngonium	syngonium	anthracnose	*Colletotrichum* sp.
63.	aglaonema	aglaonema	leaf spot	*Pseudocercospora bruneiensis*
64.	mawar	rose	crown gall	*Agrobacterium tumefaciens*
65.	hibiscus	hibiscus	flower blight	*Choanephora cucurbitarum*
66.	helicornia	crab claw	leaf spot	*Curvularia* sp.
67.	arachis	ornamental arachis	anthracnose	*Colletotrichum truncatum*
68.	bunga bayam	gomphrena	leaf spot	*Pseudocercospora globosa*
69.	crown of thorn	prickly cactus	flower blight	*Botrytis ricini*
70.	siantan	ixora	leaf spot	*Pseudocercospora ixoricola*
71.	bunga melor	jasmine	leaf spot	*Pseudocercospora jasminicola* var. *effusa*
72.	polyscias	polyscias	leaf spot	*Cercospora polysciatis*

73.	polyscias	polyscias	leaf spot	*Colletotrichum* sp.
74.	polyscias	polyscias	algal leaf spot	*Cephaleuros virescens* ?
75.	puding	croton	root rot	*Fusarium oxysporum*
76.	salix	salix	leaf spot	*Pseudocerospora salicina*
77.	pakis	fern	leaf spot	*Pseudocerospora thelypteridis*
78.	cordyline	cordyline	leaf spot	*Phyllosticia* sp.
79.	coprosoma	coprosoma	rust	*Puccinta* sp.
80.	pedilanthus	pedilanthus	powdery mildew	*Oidium* sp.
81.	Manila palm	Manila palm	leaf spot	*Pseudocercospora rhapisicola*
82.	royal palm	royal palm	sooty mold	*Trichopetotheca* sp. ? (*Capnodium* ?-ed.)
83.	royal palm	royal palm	sooty mold	*Brooksia tropicalis* ?
84.	royal palm	royal palm	leaf spot	*Annellophora* sp. ?
85.	malawaring	sealing wax palm	leaf spot	*Sicrosporium* sp.? (*Collectotrichum* sp.? –ed.)
86.	pokok kurma	date palm	false smut	*Graphiola phoenicis*
87.	hydrangea	hydrangea	leaf spot	*Corynespora cassiicola*
88.	bunga jepun	nerium	stem rot	*Botryodiplodia theobromae*
89.	ophiophagon	ophiophagon	leaf blight	*Phoma* sp.
90.	acacia	acacia	powdery mildew	*Oidium* sp.
91.	plane tree	plane tree	powdery mildew	*Microsphaera platani* ?

D.	**Miscellaneous crops and medicinal plants**			
Local name		**Common name**	**Disease**	**Pathogen**
92.	keladi	taro	anthracnose	*Colletotrichum* sp.
93.	sireh	betel leaf	leaf spot	*Myrothecium roridum*
94.	ubi manis	sweet potato	leaf spot	*Cercospora ipomoeae*
95.	ubi manis	sweet potato	anthracnose	*Colletotrichum* sp.
96.	rumput	grass	leaf spot	*Cercospora glauciana*
97.	angsana	pterocarpus	leaf spot	*Pseudocercospora pterocarpicola*
98.	sambung	blumea	leaf spot	*Pseudocercospora pterocarpicola*
99.	buloh	bamboo	leaf spot	*Pseudocercosporella bambusae*
100.	mimi sopan simalu	phyllanthus	powdery mildew	*Oidium phyllanthi*
101.	mikania	mikania	leaf spot	*Cercospora viegasii*

Existing programmes (management efforts & awareness campaigns) on IAS at the national level.

One of the lead agencies responsible for addressing alien species in the country is the Plant Protection Unit of the Department of Agriculture. The unit is responsible for the prevention of the introduction of dangerous pests and diseases which are harmful, and takes action under the "Agricultural Pest and Noxious Plants Act" of Brunei Darrusalam. Under that act, all plants or plants materials, animals and animal products imported into Brunei Darussalam must be free from pests and diseases. The DoA also carried out an awareness programme among farmers and importers in the country.

Government agencies, ministries and non-governmental organizations that could potentially be involved with IAS management

- Department of Agriculture, Ministry of Industry and Primary Resources;
- Department of Fisheries, Ministry of Industry and Primary Resources;
- Department of Forestry, Ministry of Industry and Primary Resources;
- Department of Environment, Parts and Recreation, Ministry of Development;
- Department of Museum, Ministry of Culture, Youth and Sports;
- University of Brunei Darussalam.

Priorities identified for future work and strategies within the country to identify priorities for management and policy recommendations

- Accede to the Convention on Biological Diversity;
- Set up a working group of various relevant government agencies and NGOs;
- Awareness raising on the issues of IAS to all sectors of the society;
- Strengthening acts and regulations on IAS;
- Carry out inventory on invasive alien species;
- Train more personnel to become experts in addressing issues of IAS.

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Indonesia

Invasive Alien Species in Indonesian national parks: Acacia nilotica in Baluran National Park and Cervus timorensis in Wasur National Park

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Overview

Indonesia is an archipelago of more than 17,000 islands, extending 5,000 km along the equator and spanning two major biogeographical realms, Indo-Malaya and Australia. The national parks are designed to protect ecosystems and conserve most of the native flora and fauna. Unfortunately, some parks are facing serious threats due to the threats posed by invasive alien species. This paper provides a brief overview of the threat of invasive alien species of *Acacia nilotica* in Baluran National Park and Timor deer *Cervus timorensis* in Wasur National Park. Chemical and mechanical control programmes have been attempted against *A. nilotica*, but without much success. Wasur National Park had Timor deer introduced to it in 1928. The deer population has increased significantly since then, and is now impacting native herbivores as well vegetation important for maintenance of water flows through wetlands of the park. A programme of control based on harvesting was started in 1999, but its impacts on the deer populations are not yet known.

Background

Indonesia is an archipelago of more than 17,000 islands, extending 5,000 km along the equator and spanning two major biogeographical realms, Indo-Malaya and Australia. Indonesia has a system plan for parks and protected areas, to conserve ecosystems. The Indonesian government has already designated 52,415,500 ha as conservation areas, including more than 11,000,000 ha within 40 national parks. The national parks are designed to protect ecosystems and conserve most of the native flora and fauna. Unfortunately, some parks are facing serious threats due to the threats posed by invasive alien species.

This paper provides a brief overview of the threat of invasive alien species of *Acacia nilotica* in Baluran National Park and Timor deer (*Cervus timorensis*) in Wasur National Park.

Baluran National Park

Baluran National Park is located in the eastern part of Java island, and consists of a total area 27,868 ha. Habitat types are diverse, ranging from savanna grasslands and monsoon forests to mangrove forests. The savanna grasslands are dominant, occupying 10,000 ha. There are over 400 species of plants, 147 species of birds, and 29 species of mammals, including protected species such as *Bos sondaicus, Cervus timorensis, Bubalus bubalis, Muntiacus muntjak, Cuon alpinus,* and *Panthera pardus.*

Alien invasive species in Baluran National Park

The Baluran National Park has been particularly vulnerable to invasions by alien species, due to human activities. There is a large human population living near this park and consequently the ecology, inclusive of the habitats of the park have been severely disturbed. For example, people around the park tether their domesticated buffalo and cattle inside it. At least three IAS are established in the Baluran National Park: namely *Acacia nilotica*, domesticated cattle and domesticated buffalo.

⇒ *Domesticated cattle and domesticated buffalo*

The populations of both domesticated cattle and buffalo were estimated at 100-150. These species were shepherded in the park and became competitors of endemic mammal species for food in the savanna grasslands. As a result of awareness campaigns by the national park officers, people around the park are already aware of the harmful effects caused by their herds on native species. Now all domesticated animals have been moved out of the Baluran National Park.

⇒ *Acacia nilotica*

The earliest known introduction of IAS into Baluran National Park is the invasion of *Acacia nilotica* in 1969. At that time, this species was introduced in order to prevent forest fires by acting as firebreaks. The rate of invasion increased dramatically, and the tree has had significant impacts by spreading into savanna. The savanna grassland is a food source for *Bos sondaicus* and other mammals in the Park.

The problem of this IAS is immense, as this species grows very fast. At present, this plant occupies almost 50% of 10,000 ha of savanna grassland, with a density reaching 1,245 stems per ha. This species is mainly distributed through animal dung.

Control programmes

Several IAS control programmes were implemented in Baluran National Park using chemical and mechanical control methods.

⇒ *Chemical control programme*

A chemical control programme was initiated in 1985 by the Forest Research Center (Ministry of Forestry) using the systemic herbisol indamin 720HC and 2-4 D Dinitropenol, which was injected into the trees. In 1996, a private company carried out research using the chemical Xarborisida garlon 480 Ec by peeling the branches. This chemical control was neither economically nor technically effective, because individual trees had to be treated, and this species is present in very high density and over a very wide area.

⇒ *Mechanical control programme*

Mechanical control involved the physical removal of *A. nilotica* using mechanical harvesting equipment such as a bulldozer and pulleys. The control programme was carried out from 1989 to 2000 by:

- Cutting trees;
- Eradication using pulleys;
- Pulling down trees by using bulldozers;
- Cutting down trees and burning the tree stumps.

Control using the first three methods above has not been effective so far, as the trees are still growing. However, cutting the trees and burning the tree stumps, which was initiated in 2000, was found to be effective in killing the species.

Based on evaluations, control programme for *Acacia nilotica* in Baluran National Park was not successful due to several factors:

⇒ *The characteristics of Acacia nilotica*

This species can grow in extreme conditions, both in the dry areas and in flooding prone areas. It is also a "fire proof" plant.

⇒ *Biotic and abiotic environment*

Regarding the biotic environment, *Acacia nilotica* seed in Baluran National Park is mainly spread by the activities of some herbivorous animals. The seeds attach themselves to the bodies of mammals or get carried with animal dung. In terms of the abiotic environment, open savanna grasslands receive intense sunlight and high winds, which is conducive for the spread and growth of Acacia.

Characteristics and funding of the control programme

The negative impact of mechanical control using bulldozers is high, as this disturbs the topsoil and leads to further spread of *Acacia nilotica* seeds during the flooding season. On the other hand, application of chemicals in conservation areas should be limited and strictly monitored to prevent ecological impacts.

Due to insufficient funds, the targets for control were not reached because the degree of control achieved was less than expected, while in areas which were not under control, the species spread and grew fast.

Wasur National Park

Wasur National Park is located in the southern part of Irian Jaya Island, with a total area of 413,810 ha. Habitat types are diverse, ranging from monsoon forests, savanna grasslands, freshwater habitats and mangrove forests. There are over 142 endemic plants, 72 fish, 21 reptiles, and 80 mammal species in the park, the latter including *Macropus agilis* (kangaroo), *Darcopsis veterum,* and *Thylogale brunii*. Out of 403 species of fauna, 74 are endemics.

Timor deer (Cervus timorensis) as an invasive alien species

Timor deer (*Cervus timorensis*) is listed as a protected species and was introduced to Irian Jaya in 1928 during the Dutch colonial period. The population of this species has increased significantly since then. For example, a 1990 survey estimated the population at 5,985, whereas in 1999, a survey estimated it at 9,173 animals. This species is known to have had significant impacts as a competitor with kangaroos, for sources of food. Moreover, *Cervus timorensis* also feeds on a grass species, *Stachytarpheta urticifolia* that grows along river banks. This grass plays an important role in protection of wetlands by prolonging the duration of water flow, reducing water currents flowing to the sea. Consumption of this grass by *Cervus timorensis* will shorten time for flow of water and possibly lead to erosion.

Harvesting control programme

Timor deer, which is harmful to native biodiversity, also provides an important source of food for people around Wasur National Park. Its antlers are used for handicrafts. Based on this consideration, the Ministry of Forestry released Decree no.682/Kpts-VI/1998, establishing the species as a game animal in Irian Jaya Province with effect from 1999, to enable use of its antlers.

Ideally, harvesting of this invasive alien species should reduce and hold the population below its carrying capacity. This can result in benefits to native species which are able to coexist better with moderate densities of the introduced species. However, results of the harvesting programme on *Cervus timorensis* as a game animal are not yet known, since no survey has been conducted since the decree.

Recommendations

- Carry out research to find alternative control methods;
- Develop strategies and guidelines to control and eradicate invasive alien species;
- Establish national legislation on prevention and control of IAS;
- Involve the local people around national parks to mitigate the impacts of IAS.

Laos

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Overview

Lao People's Democratic Republic, or Laos, is situated in the center of the Southeast Asian peninsula, sharing borders with China, Thailand, Myanmar, Vietnam and Cambodia. This geographic situation renders Laos landlocked, which gives it a favorable situation as an economic, cultural and environmental crossroads, if appropriately managed. Lao PDR ranks as one of the biologically richest countries in the region, not only because of its high degree of taxonomic diversity or endemism, but because a significant proportion of the country is covered by primary forest. Even though there have been introductions of alien species into Laos for many centuries, especially in the agricultural sector, there is no detailed research undertaken on the positive and negative impacts of alien species introductions in the country. However, destructive impacts of serious IAS on rural household incomes are evident, and farmers have begun to use pesticides much more than in the past to combat invasive plants and animals that threaten their crops. Prevention and management of IAS in Laos is still in its infancy, due to many constraints, including the low level of awareness of the negative impacts of IAS within Laotian society. There is a crucial need for the Lao Government to take the destructive impacts of IAS seriously, before it finds the country in a critical state.

Introduction

Geographic background

Lao PDR, or Laos, formerly known as the "Country of a Million Elephants," is a country of rolling mountains and plateaus (about 85% of its territory), where two thirds of the country ranges in altitude from 200 to 2820 m. This feature is a barrier to the development of economic infrastructure for transportation, communications and production, but it creates wide variations in climate, soils, and ecological niches leading to locally adapted and diverse biota, which supports a variety of agricultural practices and lifestyles. Two weather seasons predominate, a monsoon season (from May to September) and a dry season. Annual rainfall varies from 1,300 to 3,000 mm, but often falls short of the level needed for paddy rice farming. Localized drought and flooding create periodic crop failures, resulting in food shortages severely affecting the very poor. The Mekong River, originating in the Himalayan range, traverses the entire length of the country with most of the country's rivers flowing into it. It provides fertile floodplains for agriculture, and also serves as a main artery of transport and water. The tributaries of the Mekong River within the country hold a tremendous potential for national hydropower development.

The country is endowed with rich natural resources, such as forests, water, high levels of biodiversity and good deposits of minerals. Development of these riches is critical for laying a solid economic foundation for the country. However, this depends heavily on the rational extraction and sustainable use of natural resources, and maximizing human resource potentials within Laos.

Socio-economic background

The Lao PDR remains predominantly a rural society, with only 25% of the population classified as urban in 2000. Its population is composed of three main ethnic groups, which brings together 48 ethno-linguistic groups, engendering a rich diversity of cultures and customs.

Although much has been invested since 1975 to upgrade education levels, particularly since 1986 by the adoption of the New Economic Mechanism, there are still inadequate education facilities. Poorly developed communication and transportation infrastructure also seriously affects the rural areas of the country. This is the result of many factors, but is largely related to the lack of capital for public

spending. The agriculture and forestry sectors still remain the basis of national socio-economic development. The Government of Laos therefore strives to protect this resource base from wasteful use and degradation.

The socio-economic development plan 2001-2005 has two main goals: to strengthen the economic base of the country and to eradicate poverty in order to improve the living conditions of the people. Furthermore, there are eight national priority programmes: Food self-sufficiency; Stopping slash and burn shifting cultivation; Market production; Basic infrastructure development; Improved economic cooperation with other countries; Rural development; Human resources development; and Development of the service sector. It is a declared goal of the Government to lift the country out of poverty by the year 2020, so that it would be among the developing countries and no longer among the least developed countries.

Natural environment

Lao PDR ranks as one of the biologically richest countries in the region, not only because of its high rate of taxonomic diversity or endemism, but because a significant proportion of the country is covered by primary forest. It provides habitats to more than 250 endemic species of wildlife, out of which some are considered as threatened or endangered internationally: 67% of large mammals, 53% of bats, 6% of insectivores, 14% of murid rodents, 22% of birds, 25% of reptiles, and 2% of the amphibians.

The Kouprey and the Javan Rhinoceros, both among the most seriously threatened large mammals in the world, are thought to survive in the southern part of the country. Wetland surveys reveal that some of the country's more than 25 wetland areas support populations of endangered species, such as the Siamese crocodile *Crocodylus siamensis* and the eastern form of the Sarus Crane *Grus antigone*. Several new species of mammals, such as the Saola and large-antlered Muntjac, were discovered during the 1990s.

Floral lists are based largely on the work of Vidal (1960), who recorded 1446 species in 754 genera, nearly all of which are trees and shrubs. Consideration of known species of orchids would add another 300 species according to estimates made by the IUCN, but these figures represent only a fraction of the true magnitude of the flora. Laos's rich biological and cultural diversity has also given rise to a diversity of agro-ecosystems. For example, 13,600 genetic varieties of rice have been identified from this country. This is second only to India, a country with 14 times the area as Laos and with 200 times as many people (IRRI, cited by the State Planning Committee 2000).

The main environmental issue is deforestation, mainly due to mismanaged logging, conversion of forest land to other uses under rapid population growth, and activities of local resource users in maintaining a subsistence base in the face of external competition for the use of forest resources. The key elements of this issue are: (i) lack of a system for forest management, and lack of incentives for concessionary operators to carry out conservation management practices, (ii) encroachment of upland areas by lowland farmers, (iii) declining productivity of shifting cultivation practices, (iv) impacts of forest fires. As a consequence of rapid disappearance of forests, there is severe soil erosion, particularly along important bank rivers, loss of biological resources and degradation of watersheds.

Other environmental issues include urban environment problems, mismanaged mineral exploitation, and the need to ensure proper development of the industrial and transportation sectors, which unless planned thoroughly at the outset, can lead to severe environment damage.

Legislation, policy and institutions

The aim of the Lao PDR Government is to undertake national socio-economic development with minimal impact on the environment, along with sustainable use of natural resources, while preserving its fine customs and traditions. This will has been reflected in all National Socio-Economic Plans, the country's Constitution, legislation, the *National Environment Action Plan*, and in national priority programmes.

The Government recognizes the need to strengthen established institutions in charge of overall environment management, and to define legal and regulatory frameworks and procedures across sectors, to ensure that environment concerns become an integral part of development planning.

Legislation

Protection of the environment in the Lao PDR is anchored in its Constitution: "*All organizations and citizens must protect the environment and natural resources; land, underground, forest, fauna, water resources and atmosphere.*"

Since then, many pieces of legislation have been promulgated, such as the *Decree on Prohibition of Wildlife Trade* (1986), *Decree on the Management and Protection of Wild Animals*, and on *Hunting and Fishing* (1989), *Decree on the establishment of National Protected Areas* (1993), *Quarantine legislation* (1994), *Forest Law* (1996), *Water Resources Management Law* (1996), *Plant Application legislation* (1996), *Land Law* (1997), *Mining and Mineral Resources Law* (1997), *Transportation Law* (1997), *Electricity Law* (1997), *Environment Protection Law* (1999) including biological resources conservation, and *Pesticide Law* (2000). The bio-access draft legislation, which contains measures related to legal and illegal exportation of indigenous species, and introduction (legal and illegal) of alien species, is still being discussed at the central level of the government and will be promulgated in the near future**.**

Implementation of the above legislation has faced some constraints, such as the lack of qualified people, limited budgets, and a population not yet used to legislative procedures. Effective implementation requires institutional strengthening, adequate budgetary allocations, greater awareness in the population of the importance of the law (on why, when and how to use their rights) and the value of the nation's biological resources, and a proper understanding of positive and negative impacts of alien species.

The Lao PDR became a Party to the CBD in 1996, and is in the process of ratifying the Ramsar and CITES conventions, among others. The Science, Technology and the Environment Agency, together with the Ministry of Agriculture and Forestry, is formulating the National Strategy and Action Plan on Biological Resources, which is expected to be promulgated by the end of the year 2003. The country became a member of the ASEAN in 1997. The principal legal instrument of ASEAN with nature conservation obligations for Laos is its Agreement on the Conservation of Nature and Natural Resources.

Policy

The Lao Government focuses on *in-situ* conservation, economic measures, and co-operation with relevant institutions at the regional and international level based on mutual interests, in order to ensure steady sustainable use and conservation of biological resources.

Prime Ministerial Decree 164 established the *National Biodiversity Conservation Areas* system in 1993. It named and mapped (at 1:500 000 scale) 18 "*Pa Sa Nguan Heng Sat*, or "National Preserved

Forests," and the term "*National Biodiversity Conservation Area*" was adopted for English usage (Berkmüller *et al*. 1995a). At present, there are 20 national biodiversity conservation areas (or national protected areas), which represents 14% of the total area of the country. It is generally accepted that between 5% and 20% of a country's ecosystems, depending on their fragility and diversity, should be represented in a protected area system. The World Bank Congress in 1982 adopted the standard of 10% of total land area, as an appropriate target for conservation in forested countries such as Lao PDR.

The use of economic incentives for sustainable use and conservation of biological resources has been reflected in the Rural Development Programme (a National Priority Programme)[1] and the Land and Forest Allocation Programme, which gives property rights to villagers in order to encourage them to participate to forest and biodiversity conservation, using concession fees from development projects, such as from hydro-power development projects.

Institutions

The Science, Technology and Environment Agency (STEA), created in 1993 under the Prime Minister's Office, is in charge of overall management and control of environment activities at the national level. It is therefore the main manager and coordinator of activities related to the conservation and sustainable use of national biological resources.

The Ministry of Agriculture and Forestry is in charge of solving environment issues resulting from agricultural and forestry development, notably on the conservation and sustainable use of agricultural and forest biological resources. The Ministry of Public Health is mainly involved in the use of biological resources in health, particularly in the traditional medicines sector. There are also quarantine inspectors present throughout the country at central, provincial and district levels, where their duties include inspections at checkpoints, and control of import permits such as issuance of phytosanitary certificates.

Invasive alien species

There have been introductions of alien species into Laos for many centuries, especially in the agricultural sector for economic advancement. A good example is coffee, introduced in the 18th century and now one of the main export crops of Laos. There is no in-depth research undertaken on the impacts of these introductions in the country. However, destructive economic impacts of IAS on rural households can be observed, including the golden apple snail (*Pomacea* sp.), the disease bakanea (*Fusarium fujikoroi*), and the weeds *Echinochloa colonum*, *E. crusgalli*, *Mimosa invisa*, and *Mimosa pigra*.

Case study: weeds

The perception among farmers is that weed problems have increased severely over the last twenty years due to the spread of many new species introduced from abroad. In the upland agricultural systems in the northern provinces of Laos, *Mimosa invisa* and *M. pigra* have become increasingly problematic, whereas in the lowland rice production systems, the grasses *Echinochloa colonum* and *E. crusgalli* are nuisances. Farmers usually weed their fields by hand, but this has become very inefficient and as labor is limited, farmers have started gradually using commercial herbicides, which over the long term could

[1]The Rural Development Program in Phongsaly District is among the best in the country. It has had close consultation with the local community in formulation and implementation. It aims to build capacity of local staff and the population while gradually increasing family incomes in targeted groups and contributing to conservation of biological resources of the district, which are of provincial and regional importance. The Phou Dandin National Protected Area (NBCA), in Phongsaly District, has significant regional biodiversity value, according to the IUCN.

lead to serious environmental problems. Studies to find appropriate solutions to these issues have been undertaken, but due to budgetary and staff constraints, have not been sustained sufficiently to arrive at suitable conclusions.

Case study: golden apple snail, Pomacea sp.

The golden apple snail (GAS) (*Pomacea* sp., from Thailand) was first introduced to Sikhotabong District in Vientiane Municipality in 1991, and spread into three villages, Viengsavanh, Nahai and Phosi. First signs of damage to lowland rice fields were reported in 1992. In 1994, these snails were brought from Vietnam to northern provinces of the country, mainly as a food source.

Since then, GAS has spread to 10 of Lao PDR's 17 provinces, mainly through interconnected waterways and by human transport. The snail attacks young rice seedlings up to 20 days after transplanting, and consequently fields infested with GAS have to be re-planted several times. Snail shells can cause severe injuries to people working in the field. Collecting GAS in the field has become inefficient in severely infested areas, and due to the low availability of farm labour, farmers have turned to application of non-selective chemicals. But these chemicals pollute water, and are a serious threat to other aquatic organisms as well as the health of people working in the paddy fields.

Many different control techniques have been developed by the Laos Agricultural Extension Center and transferred to farmers. The core methods focus on integrated snail management by a combination of different techniques applied simultaneously, such as: closing the entrance points of snails to rice fields, hand picking, transplanting with old seedlings, reducing water levels in the rice field, using a variety of local cultural control methods, and emphasizing that control should be done seasonally. Still, many people in Lao PDR are unaware of the threat posed by these snails, and are attracted by the snails' colourful egg masses, collecting them as a delicacy.

Programmes to address IAS

Farmers of Laos have begun to use pesticides much more than in the past, to combat invasive plants and animals that threaten their crops. To protect the environment and consumers from harmful effects caused by misuse of mostly unregistered pesticides, the Lao government strongly discourages their use. Several research programmes have been set up to find suitable, more environmentally friendly alternatives:

a. The National Agricultural Research Center, in cooperation with the Lao-International Rice Research Institute (IRRI) project, has initiated research experiments testing the efficiency of several biological controls against GAS.

b. The Northern Agricultural and Forestry Research Center in Luang Prabang, together with the Lao-IRRI project, has started several control methods against weeds.

c. The Australian Cooperation for International Agricultural Research (ACIAR), is supporting a 4–year project (1999-2002) focusing on rodent control techniques in the upland agricultural production systems.

Conclusion and suggestions

Prevention and management of IAS in Laos is still in its infancy, due to constraints on qualified staff, finances, appropriate information, legal framework, implementation of enacted legislation, and the low level of awareness in Laotian society on the many negative impacts of IAS. There is a crucial need for

the Lao Government to take the destructive impacts of IAS seriously, before they become a major development issue across the entire country.

Therefore, in order to effectively prevent and manage IAS in Lao PDR, the following are suggested:

a. Promotion and development of economic incentives on the sustainable use and conservation of national biological resources, specifically using indigenous species;

b. Promulgation of legislation related to the introduction of IAS, emphasizing cooperation and support of local communities;

c. Strengthening capacity of Laotian staff, notably in taxonomy, tropical botany and zoology;

d. Establishment of a national network or working group on IAS prevention and management;

e. Promotion of research on impacts of alien species, notably the destructive effects of IAS;

f. Promoting awareness at all level of the Lao society and in schools;

g. Creation of a national biodiversity conservation fund, in order to effectively address the IAS issue in a sustainable manner;

h. Cooperation with relevant sub-regional, regional and international institutions, such as information sharing, capacity strengthening and research collaboration.

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Annex 1. List of quarantine pests and diseases in Lao PDR

Commodity/host plant	Common name	Scientific name/causal organism
fresh plant products (fruits, vegetables, cut flowers, ornamental branches)	California scale Japanese rod scale Japanese beetle	*Quadraspidiotus perniciosus* *Lopholeucaspis japonica* *Popillia japonica*
fruits and vegetables (excluding root crops)	Mediterranean fruit fly Mexican fruit fly Queensland fruit fly great tangerine fly other fruit flies	*Ceratitis capitata* *Anastrepha ludens* *Dacus tryoni* *Tetradacus citri* *Ceratitis* sp., *Anastrepha* spp.
stored products (grains, leguminous seeds, meal, etc.)	Khapra beetle broad-nosed grain weevil dried bean weevil	*Trogoderma granarium* *Caulophilus latinasus* *Acanthoscelides obtectus*
vegetative plant parts	Texas root rot California scale Japanese rot scale Japanese beetle fig wax scale	*Phymatotrichum omnivorum* *Quadraspidiotus perniciosus* *Lopholeucaspis japonica* *Popillia japonica* *Ceroplastes rusci*
rice	white tip nematode rice stem nematode white leaf (hoja blanca) black streaked dwarf stripe	*Aphelenchoides oryzae* *Ditylenchus angustus* virus virus virus
maize	white-fringed beetle broad-nosed grain weevil bacterial leaf blight dry rot	*Graphognathus leucoloma* *Caulophilus latinasus* *Erwinia stewartii* *Diplodia zeae*
soybean	soybean cyst nematode	*Globodera glycine*
groundnut	white-fringed beetle dried bean weevil groundnut rosette groundnut rust	*Graphognathus leucoloma* *Acanthoscelides obtectus* virus *Puccinia arachidis*
tobacco	Colorado potato beetle tobacco blue mold	*Leptinotarsa decemlineata* *Peronospora tabacina*
coffee	coffee berry borer American leaf spot coffee berry disease tracheomycisis	*Hypothenemus hampei* *Omphalia flavida* *Colletotrichum coffenum* CBO-strain *Gibberella xylarioides*
sugarcane	white-fringed beetle white cane grub leaf scald nematode	*Graphognathus leucoloma* *Phytalus smithi* *Xanthomonus albilineans* *Tylenchorhynchus martini*
potato	Colorado potato beetle white-fringed beetle potato tuber worm potato cyst nematode potato cyst nematode black wart ring rot powdery scab	*Leptinotarsa decemlineata* *Graphognathus leucoloma* *Ptthorimaea opercullella* *Globodera pallida* *Synchytrium endobioticum* *Corynebacterium sepedonicum* *Spongospora subterranea*
cassava	Bacterial blight	*Xanthomonus manihotis*
sweet potato	Foot rot Stem rot White rust disease Virus diseases	*Plenodomus destruens* *Fusarium oxysporum* f.sp.*batatas* *Coleosporum ipomoeae* viruses

cotton	cotton boll weevil pink boll worm white-fringed beetle bacterial leaf blight cotton wilt Texas rot	*Anthonomus grandis* *Pectinophora gossypiella* *Graphognathus leucoloma* *Xanthomonas malvacearum* *Fusarium oxysporum* f. sp. *vasinfectum* *Phymatotrichum omnivorum*
tomato	tomato bacterial canker potato cyst nematode potato cyst nematode	*Corynebacterium michiganense* *Globodera rostochiensis* *Globodera pallida*
onion and other *Allium* spp.	smut	*Urrocystis cepulae*
citrus	mal secco tristeza, quick decline	*Deuterophoma tracheiphila* virus
tea	phloem necrosis blister blight root lesion nematode root knot nematode	virus *Exobasidium reticularum* *Exobasidium vexans* *Pratylenchus loosi* *Meloidogyne brevicauda*
coconut and other palms	palm weevils lethal yellowing heart rot red ring disease cadang cadang	*Rhynchophorus* spp. mycoplasma-like organism *Phytomonas* sp. *Rhadinaphelenchus cocophilus* virus-like agent
banana and other Musacease	moko disease bunchy top black sigatoka	*Pseudomonas solancearum* virus *Mycosphaerella fijiensis* var. *difformis*
pineapple	mealy bug	*Dysmicoccus brevipes*, new var.

Source: Quarantine regulations, Ministry of Agriculture & Forestry of Lao PDR No.0639/MAF, d. 2 July 1993

Malaysia

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Overview

The issue of alien species invasions is new to Malaysia, although it has been present in many parts of the country for very long time. In particular, the agricultural sector has been badly affected by invasive alien species. In addition, some IAS negatively affecting wildlife are now slowly spreading within the country. To date in Malaysia, there is no comprehensive, coordinated, monitoring and cataloguing programme for invasive alien species. Therefore, there are no official statistics on the total number and types of such species. More effective implementation of the Plant Quarantine Act and plant quarantine regulations by the Department of Agriculture could potentially prevent introduction and establishment of more IAS in the future. At present, there is not much research carried out on IAS, nor is there cooperation between government and non-governmental organisations and universities to mitigate the problems caused by IAS. What Malaysia needs now is an agency that can concentrate on the issue of invasive alien species.

Introduction

Throughout the history of the planet biological invasions have been an important result of evolutionary forces. Most invasions come from human actions, often deliberate or accidental (Williamson, 1996), apart from floods, droughts or strong winds. The introduction of alien species may be deliberate, such as through farm animals, pets, ornamental plants and crop plants, or accidental through contaminated trade commodities and travel. The deliberate introductions were meant to fulfill physical and social needs of humans. In the early days, introductions were few in number, but with modernization of transportation and with increasing trade, passage of these species all over the world has increased manyfold.

The presence of spatial and temporal disturbances may increase the degree of invasion by alien species over native species (Maron and Connors, 1996; Symstad et al., 1998). Degradation of natural habitats, ecosystems and agricultural lands (e.g. loss of cover and soil, pollution of land and waterways), global climate change, among several other causes have been proposed as factors facilitating invasions. Invasive alien species are often aggressive, harmful or destructive in their new habitats, and pose problems to native species by competing for food, territory and other resources, resulting in population decline or extinction. In the case of alien plant invasions, for example, the damaging effects on local and regional diversity of native plants are increasingly becoming a serious conservation problem (Levine and D'Antonio, 1999). This paper presents an overview of IAS known to cause problems to the natural environment and economy, as well as their present state of management in Malaysia.

Invasive alien species in Malaysia and their ecological and economic impacts

In Malaysia, there is still no comprehensive catalogue or coordinated monitoring programme of IAS, and thus no official statistics on the total number and types of IAS. A list of IAS identified as of agricultural importance is given in Appendix 1 of this paper. Additionally, some invasive species affecting wildlife are noted here. Details of the more important IAS are given below.

⇒ Cocoa pod borer (CPB), *Conopomorpha cramerella*

In Malaysia, CPB was first detected in Sabah in August 1980. Its spread is suspected to be through cocoa planting material. Initially, the infestation was confined to 4,000 ha of cocoa plantings in Tawau, Sabah. By mid-1983, 2.5 years later, all major cocoa growing areas in Sabah were infested. Within the same period the pest had established itself in Sarawak, the neighboring state. In Peninsular Malaysia, cocoa was free of the pest until 1986, when it was detected in about 700 ha of cocoa in Melaka. Subsequently, the pest was detected in other major cocoa growing areas of the country. When it was first detected, an attempt was made by the federal government to contain and eradicate this pest, but this failed. Today the CPB is the most important insect pest of cocoa in Malaysia.

The larvae of the insect bore into the cocoa pod and feed on the pulp and funicles, which causes cocoa beans to clump and stop development. This may make them difficult to remove from the pods, and leads to malformed small and low quality beans. Although overall economic loss is difficult to ascertain, crop loss in badly infested holders can be very severe, and losses up to 30% are not uncommon.

⇒ Diamondback moth (DBM), *Plutella xylostella*

It is believed that this insect became established in Malaysia for three reasons: most of its preferred hosts were imported plants; it has few endemic natural enemies in Malaysia; there is only one congeneric species in Malaysia. *Plutella xylostella* was first recorded in Malaysia in Fraser Hill in 1925. By 1934, the insect was found in Cameron Highland, which was newly opened for cultivation of temperate vegetables. By 1941, it was reported that the DBM was a major pest of cabbage in the Cameron Highland.

Today, DBM is the major pest of brassicas in both the highland and lowland areas of Malaysia where cabbage and other crucifers are grown. Outbreaks and high incidence of infestations are reported yearly. Because there are no effective natural enemies, growers depend solely on insecticides to control it. As insecticides have been used intensively and indiscriminately for control, DBM has developed resistance to all major groups of insecticides, requiring use of newer and more effective insecticides. Increase of insecticide resistance leads growers to use higher doses with increased frequencies of application, thus increasing production costs. The extensive use of insecticides has created more problems than solutions. Among the most common effects of heavy use of insecticides are higher levels of insect resistance, insecticide residues on crops, hazards to non-target organisms and environmental contamination.

⇒ The beet armyworm, *Spodoptera exigua*

The beet armyworm is an important crop pest, widespread in sub-tropical, tropical and temperate regions. Prior to the 1990s it was not reported from Malaysia. This pest was first detected in 1996 attacking a hot pepper crop in Ayer Hitam Johor. Subsequently, sporadic, small outbreaks were reported from other parts of Johor and Melaka. It is now an important pest of vegetable crops, such as onions, brinjal, legumes, chilli and crucifers. It is very difficult to control as it has developed resistance to most insecticides.

⇒ Golden apple snail, *Pomacea canaliculata,* and black apple snail, *Pomacea insularis*

Pomacea spp., which are indigenous to South America, were first introduced to Taiwan in 1980, Japan in 1981, the Philippines in 1982 and Thailand in 1986 for commercial purposes. They were illegally brought to Malaysia for the same purpose and first detected in fish ponds in Puchong and Subang, both in Selangor, in 1991. The species in Puchong was identified as *P. insularus*, while the species in Subang was *P. canaliculata.* Following the discovery, a nationwide survey was conducted to detect the presence of these snails. It showed that the snail was found only in a few specific, isolated areas such as fish ponds, unused tin mines, aquaria and in a small rice field at Kg. Pengkalan Semeling, Kedah. Containment and eradication measures were then implemented, and succeeded in slowing, but not stopping the spread. In some areas, the snails made their way to nearby rivers, water drains, irrigation canals and rice fields. Currently, snails have been detected in about 5,000 ha of rice fields in Perak, but there are no reports of damage to rice plants.

The snail can easily spread through the extensive networks of irrigation canals, and this is potentially a threat to large rice-growing areas in the near future. Where the crop is raised through wet direct seedlings, potential damage could be devastating, as this provides an environment conducive to snail infestations. The snail feeds voraciously on young rice seedlings under wet conditions, causing great losses to farmers.

⇒ Papaya ring spot virus (PRSV)

Papaya ring spot virus originates from South America. In Asia, it was first detected in Kaoshung, Taiwan in 1975, and in Luzon, Philippines in 1982. In Malaysia, it was first detected from the southern part of Johore in 1991. Following this discovery, a nationwide survey was carried out to detect the disease, followed by twice-yearly surveys. The results show that the PRSV occurs only in southern Johore while the rest of Malaysia, including Perak, which is the second biggest papaya producing state after Johore, is still free from PRSV.

Since the PRSV was first detected, the areas planted with papaya decreased drastically as all plants in infested areas were removed to eliminate the source of the virus. Furthermore, there are no new plantings, as the growers move out of infested areas to safe locations. Very soon papaya cultivation in Johore will be wiped out.

⇒ Citrus greening disease bacterium, *Liberobacter asiaticum*

Citrus greening is a highly destructive disease of citrus. The bacterium probably originated in China, and seriously affects production in Asia, including Malaysia. There is uncertainty on how and when the disease was introduced into Malaysia. In the late 1960s, the government through various agricultural agencies and growers' associations made large scale citrus plantations, but after some years these and many other areas in the country were abandoned due to a disease causing a slow decline of the trees. Most probably this was due to greening disease, which was confirmed in Malaysia only in 1989.

The disease is the major stumbling block to the healthy growth of the citrus industry. Citrus growers resort to insecticides to protect their crops from vectors that spread this greening disease. In the long term, this will contaminate the environment, trigger insect resistance and resurgence of pest populations, and increase the costs of production.

⇒ Sacbrood virus disease of honey bees

Sacbrood is a viral infectious disease which affects the broods of honey bees. It is a widely distributed disease, but usually does not cause serious losses. Prior to 1994, the indigenous bee, *Apis cerana indica* was reared in modern boxes to produce honey, and there was no incidence of sacbrood disease. In early 1994, *Apis cerana cerana*, which is more productive than the native bee, was imported from Southern China as a way to improve local honey production. The imported colonies were kept in Sungai Burung Selangor and Merlimau Melaka for quarantine observations. Six months after introduction, sacbrood, previously unknown in Malaysia, was found infecting nearby colonies of the native bee, *A. e. indica*. The disease spread and within six months, almost 100 percent of native bee colonies nearby were wiped out. Since then, containment measures has been implemented to prevent further spread. The measures have successfully confined the disease to Selangor, Melaka, Johor and Terengganu. The rest of the country including Perak, which keeps most of the native colonies, is still free from the disease. Sacbrood is a deadly disease, causing economic hardship to beekeepers and eradication of wild colonies. This could lead to the loss of income for farmers, and pollination failure for local plants.

⇒ Itch grass, *Rottboellia cochinchinensis*

Itch grass is a native of India, and possibly Indochina. It is believed to have been introduced to Malaysia from Thailand, as it was first detected in Perlis, a border state of Thailand in 1980. Following this, a preliminary survey was conducted and it was found growing in isolated patches in Perlis Plantation Bhd, a sugarcane plantation. The weed was observed to be abundant along small streams around swampy areas and ponds in the plantation. By 1992, it had spread throughout the plantation.

The occurrence of this weed poses a potential threat to agriculture in general. Though at present confined to sugarcane areas and along roadsides, this noxious weed could establish itself in crops such as groundnuts, cassava, citrus, rice, papaya and pineapples. Once established, its rapid growth and spread makes it a very aggressive competitor.

⇒ Water hyacinth, *Eichhornia crassipes*

This plant is a native of Amazonia, Brazil. Beguiled by its beautiful blue flowers, man has brought this plant from continent to continent. It was first brought to Singapore from Hong Kong in 1963. Chinese villagers found it suitable for pig feed, and cultivated it in tanks and ponds for this purpose. It spread into sluggish waterways and became a pest. In Malaysia, this weed thrives in still or slowly moving waters, propagates very rapidly by seeds and offsets, and now is a serious threat to irrigation and drainage canals and all kinds of aquatic environments. It is one of the world's most serious water weeds, and its domination can threaten or eradicate other species.

⇒ Aquarium water moss, *Salvinia molesta*

Salvinia molesta is native to Southeastern Brazil. It was introduced into Malaysia as an ornamental plant but later escaped into the wild. At the moment, only east coast states are free of this weed. It rapidly reproduces and can completely occupy rice fields and drainages. A full cover of *Salvinia* in a rice field may depress yield. It has also been observed to completely block drainage and irrigation canals.

⇒ Timor deer, *Cervus timorensis*

The indigenous deer species in Peninsular Malaysia is the Sambar deer (*Cervus unicolor*). In the 1980s, the Department of Veterinary Services (DVS) introduced an alien deer, the Timor deer in Peninsular Malaysia. Some of the animals were placed in the Department of Wildlife & National Parks (DWNP) captive breeding centers. The DWNP has recently ceased its captive breeding programmes. Breeding of the Timor deer is now undertaken at more than ten captive breeding centers in the country, which are managed either by the Department of Veterinary Services or private companies.

The Timor deer was introduced for breeding research purposes, to alleviate poaching pressure on the indigenous deer, and for commercial purposes. DWNP's research involved investigating methods for captive breeding at a high productivity level. The Timor deer was found to breed very well. After the Department's success in the captive breeding programme of this species, the expertise and knowledge was transferred to other agencies, companies or other individuals to explore the potential of exploiting the species for commercial purposes, as the price for deer meat is quite high and was felt to have considerable commericial potential. It was also felt that as the hunting season for the Sambar deer is only open for one month per year, and there is a heavy illegal hunting pressure out of season, the Timor deer could be raised to sell meat to the public from captive breeding centres.

Apart from its prolific breeding, the Timor deer can also hybridize with the indigenous deer species. If it escapes into the forest, it would also likely compete with the Sambar deer in the wild. There has to date been no research on these aspects.

⇒ Red-eared tortoise, *Trachemys scripta elegans*

This species originates from America and was introduced to Peninsular Malaysia about twenty years ago. It is popular as a pet and is not often consumed as food. According to the Protection of Wildlife Act of 1972 and the CITES convention, to which Malaysia is a party to, any activity involving trade of the species including placing it in pet shops requires an import permit. The trading of this species, however, generates good monetary returns.

It is a common practice among those who keep this species as a pet to release it into the wild when it becomes an adult. There are several reasons for this behaviour. Firstly, the tortoise is no longer regarded as an attractive pet, compared to when it is small. Secondly, it requires large amounts of food and may not be an affordable pet for some. Because of its food requirements, there is a probability that this species will compete with local tortoise species in the wild. There has been no research undertaken on this to date.

⇒ House crow, *Corvus splendens*

This species, also known as the Indian house crow, is indigenous to the Indian sub-continent. Although it is territorial during the day, it congregates at roosting sites at night. Rubbish dumps, dry weather watering points, abattoirs etc. appear to be non-territorial communal-use areas for these birds. The crow was originally introduced as a biological control agent to eat rhino beetles in oil palm estates.

Since the house crow breeds rapidly, its population has increased rapidly within a short period of time and the species has moved into urban and settlement areas. This may cause the displacement of other bird species whereever it occurs. The species is a scavenger, and its droppings pose a risk to human health. Archer (1988) showed that the species carries eight enteric pathogens likely to cause human diarrhoeal diseases. The nuisance factor of the species lies in their food-seeking behaviour, where they

often take scraps from unattended plates or cooking pots even within a few metres of humans, and in their propensity to take shiny things such as jewellery.

⇒ Philippine glossy starling, *Aplonis panayensis*

This introduced species also has similar habits to the house crow. It is known to prey on the eggs of several local bird species, potentially threatening their populations. It also perches on oil palm factories, and deposits droppings in the general area. This is an unpleasant sight as well as being unhygienic.

Management of IAS in Malaysia

Some alien species can potentially pose significant threats to agriculture (crops, animals, livestock), non-cultivated ecosystems and humans if they establish themselves in Malaysia. In this country, such species are officially listed by regulatory agencies as dangerous alien species that need to be controlled. In general, management strategies and control measures for such species are aimed to prevent, eradicate, contain, or effectively control, should its entry and establishment take place. Legislation, regulations and procedures are also provided to smoothly implement these measures. For example, The Plant Quarantine Act of 1976 and the Plant Quarantine Regulations of 1981 provide the legal framework for dealing with dangerous alien pests of plants. Effective implementation of this act could potentially prevent more introductions and establishment.

Plant quarantine is the first line of defense in managing invasive pests of plants. At an international level, inspection is recognized as the primary phytosanitary measure of quarantine that checks and certifies the presence of alien pests, in any consignment at point of origin or upon entering a country. Under this measure, prior shipment treatments may be imposed on high risk consignments from high risk origins. This activity is crucial to minimizing the risk of IAS introductions. At the national level, the Department of Agriculture is responsible for enforcing quarantine laws and has stationed 250 enforcement officers at all 49 entry points to the country. All agricultural goods are subjected to inspection at points of entry. Agricultural produce or consignments found to be infested with live pests will be held in a secure area at a port of entry until the pests have been identified. If the pest is positively identified as a quarantine pest, the consignments are either seized and destroyed or sent back to the exporting country. For the year 2000, a total of 580 consignments with 82 species of arthropods were intercepted. Of this total, only three species were found to be dangerous pests gazetted under the present act and regulations.

Besides immediate quarantine action at entry points, containment and eradication has to be carried out immediately upon detection or interception of pests at premises or any other places. Under Sections 6, 10, 11 and 12 of the Plant Quarantine Act of 1976, plant quarantine inspectors are given the authority to isolate premises or any area, and to direct eradication treatment as deemed necessary. Several contingency plans have been developed to contain, eradicate and control dangerous alien pests. The first effort to contain and eradicate a plant pest in Peninsular Malaysia was on cocoa pod borer (*C. cramerella*) in 1986, but it was not successful, likely due to the pest having spread to a bigger area by the time it was first detected, which made containment difficult and ineffective. Later, two eradication programmes were implemented after the detection of two dangerous alien pests, cocoa pod borer and golden apple snail.

When it was first detected, the Khapra beetle (*Trogoderma granarium)* was found only in one isolated rice store and was successfully eradicated. However, subsequent attempts to contain and eradicate the golden apple snail (*Pomacea* spp.) were not successful, as it was already widely distributed in irrigation canals when first detected, and effective viable control methods were not available. Apart from these, there have not been other attempts to eradicate any pest even though numerous introductions of alien pests (Table 1) have taken place. It is believed that these pests were detected only when they had

already spread widely, making containment and eradication no longer viable. In short, early detection is crucial to ensure that a pest can be contained and effectively eradicated.

Table 1. List of major IAS in Malaysia

Group	Common name	Scientific name	Probable origin	Year of detection	Distribution	Status
Insects	cocoa pod borer	*Conopomorpha cramerella*	Indonesia Philipines	1980 Sabah 1983 Sarawak 1986 Peninsular Malaysia	throughout Malaysia	major pest of cocoa
	diamondback moth	*Plutella xylostella*	Mediter-ranean	1925	Throughout Malaysia	major pest of crucifers
	beet armyworm	*Spodoptera exigua*	Thailand Indonesia	1996	Throughout Malaysia	serious pest of vegetables
	vegetable leaf miner	*Chromatomyia horticola*	Holland	1986	Cameron Highland	serious pest of vegetables
	cut flowers leaf miner	*Liriomyza huidobrensis*	Holland	1991	Cameron Highland	serious pest of vegetables
	greenhouse whiteflies	*Trialeurodes vaporariorum*	Europe	2000	Highland CH & Kundasang	pest of vegetables
Snail	golden apple snail	*Pomacea canaliculata.*	Philipines	1984	Kedah, Perak	pest of rice crop
	black apple Snail	*Pomacea insularis*	Thailand		Selangor, Sabah, Sarawak	
Plant disease	papaya ring spot virus	PRSV	South America	1991	Southern Johor	major disease of papaya
	citrus greening disease	*Liberobacter asiaticum*	China	confirmed 1989	throughout Malaysia	major disease of citrus
Honey bee disease	sacbrood virus	virus	China	1994	Johor, Melaka Selangor, Terengganu	major disease of *Apis cerana indica* – indigenous honey bee
Weeds	itch grass	*Rottboellia cochinchinensis*	Thailand	1990	Peninsular Malaysia	weed
	water hyacinth/ keladi bunting	*Eichhornia crassipes*	South America/ Amazonia	1903	throughout Malaysia	major weed in rice fields
	giant salvinia	*Salvinia molesta*	SE Brazil	unknown	throughout Malysia except east coast states	major weed in rice fields, water bodies
	hedge plant	*Cordia curassavica*	South America	unknown		weed of road sides, waste land
	siam weed	*Eupatorium odoratum*	North America	unknown	throughout Malaysia	weed in plantations
		Asystasia coromandeliana		1876	Peninsular Malaysia	major weed of oil palm lands
	barnyard grass / Sambau	*Echinochloa crusgalli*	Australia	1925	Peninsular Malaysia	most serious weed, rice fields

giant sensitive plant / Semalu-gajah	*Mimosa pigra*	Australia	1980	Peninsular Malaysia	weed of waste land
mile-a-minute weed / Ulam tikus	*Mikania micrantha*	South America	unknown	throughout Malaysia	major weed of plantation
goose grass / rumput sambari	*Eleusine indica*	Africa	unknown	throughout Malaysia	common weed in plantation
creeping sensitive plant (Duri semalu)	*Mimosa invisa*	tropical America	unknown	throughout Malaysia	weed

Pest management strategies have to be changed when alien pests become invasive, especially when they appear to be established and widespread. In general, they are no longer treated as quarantine pests, but as common pests. As such, management is no longer focused on eradication, but on reducing population size and reducing damage. The Cocoa pod borer is a classic example of a quarantine pest that lost its status as it became the most serious cocoa pest in Malaysia. Control measures are ongoing to contain population size and infestation rates below the threshold levels, so that serious economic losses can be avoided. In general, control measures are not dependent on a single method, but use a combination of chemical and cultural methods. The same overall management strategies were adopted for all IAS in Table 1.

Research bodies, either in government or the private sector, have played important roles in helping regulatory and extension bodies to manage invasive alien species. They have developed better technologies that are more effective and environmentally friendly. For example, at the beginning of cocoa pod borer invasion, control depended much on heavy spraying of pesticides. Later, better control methods were developed which achieved the same objectives, but did not depend on pesticides. Proper fruit harvesting and introduction of biological control agents has significantly controlled cocoa pod borer infestations.

Integrated pest management has been developed for another invasive species, *Plutella xylostella*, a serious pest of crucifers. Several biological control agents were imported and released against this pest, of which a few successfully established and have played a major role in regulating this pest. Other major management strategies include crop scheduling and use of environment-friendly pesticides such as insect growth regulators and bio-pesticides.

Agencies involved in managing IAS

Management of IAS is the responsibility of government agencies. Most of the alien species brought in the country will be quarantined and checked by agencies such as the Departments of Agriculture and Veterinary Services. Other relevant agencies for management of IAS are included in Table 2. Once an alien species becomes invasive, all possible means of control have to be instituted. Related government agencies will continue to monitor the invasive species situation and develop control strategies and technologies, while the implementation of control measures is expected to be carried out by individual growers. Growers usually implement control measures for prevention as well as curative action. Extension agencies such as Department of Agriculture, plays an important role in advising the regulatory agencies, individual growers as well as the general public on the effective measures to control a particular pest.

Table 2. List of major ministries, government agencies and non-governmental organisations involved in IAS management

Ministry	Agency or department	Areas of responsibility
Ministry of Agriculture	Department of Agriculture, Peninsular Malaysia (Plant Protection and Quarantine Division) Tel: +60.3.26982011, Fax: +603.26985746	crop production and plant protection, including plant quarantine services (regulation and extension)
	Department of Fisheries, Peninsular Malaysia Tel: +60.3.26982011/ 26910305	fisheries and other aquatic life, incl. related quarantine services (regulation, research and extension)
	Department of Veterinary Services Tel: +60.3.2540077/ 2540092	animals and animal husbandry incl. animal quarantine services (regulation, research and extension)
	Malaysia Agricultural Research and Development Institute (MARDI) Tel: +60.3.8943711/ 89483664	agricultural research and development
Ministry of Primary Industry	Forestry Department, Peninsular Malaysia Tel: +60.3.26988244 Fax: +60.3.26925657	forestry and forest management (regulation and extension)
	Forest Research Institute (FRIM) Tel: +60.3.62742633 Fax: +60.3.62767753	research & development, forestry and timber industries
	Malaysia Cocoa Board (MCB) Tel: +60.8.8252572 Fax: +60.8.8239575	research & development, cocoa industry
	Palm Oil Research Institute (PORIM)	research & development, oil palm industry
	Rubber Research Institute of Malaysia (RRIM)	research & development, rubber industry
Ministry of Science, Technology and Environment	Department of Wildlife, Peninsular Malaysia Tel: +60.3.90752872 Fax: +60.3.90752873	regulations and research in wildlife
Ministry of Health	Department of Public Health Tel: +60.3.26985077 Fax: +60.3.26985964	regulations and public health
	Institute of Medical Research	research and development (diseases and vectors)
Ministry of Agriculture and Fisheries, Sabah	Department of Agriculture, Sabah	regulations and extension - crops, agriculture, animal husbandry and veterinary services, marine & fresh water fisheries, drainage and irrigation (also quarantine services)
	Department of Fisheries, Sabah Tel:+60.8.8235966 Fax: +60.8.8240511	research, development and extension services in fishing industry
	Department of Veterinary Services and Livestock Industry, Sabah	research, development & extension in animal husbandry and veterinary services, including animal quarantine
Ministry of Agriculture, of Sarawak	Department of Agriculture Tel: +60.8.2441000 Fax: +60.8.2448721	agricultural research & extension – crop, livestock, inland fisheries and farmers institution, including plant quarantine services
Ministry of	Division of International Trade	multilateral and bilateral trade relations

Internat'l Trade & Industry	Tel: +60.3.62033022 Fax: +60.3.62010827	
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	University of Malaya Tel: +60.3.76977022 Fax: +60.3.7552975	teaching and research
	National University of Malaysia Tel: +60.9.89250001 Fax: +60.389256484	teaching & research
	Science University of Malaysia Tel: +60.4.6577888 Fax: +60.4.65755113	teaching and research
	Malaysia University of Sarawak Tel: +60.8.2671000 Fax: +60.8.2671123	teaching and research
	Malaysia University of Sabah Tel: +60.8.8320000 Fax: +60.8.8260730	teaching and research
Non-govt. organisations	Malaysian Plant Protection Society (MAPPS)	dissemination of information

Future work and strategies in managing IAS

Management strategies of invasive species cover three aspects: prevention; containment and eradication; and control. The prevention of alien species introduction is the first priority in managing them because containment, eradication and control are difficult, expensive and likely to be ineffective. When prevention fails, management options depend on how widely the species has spread. If the species is confined to a small area, it should be contained and eradicated. In order to minimize introduction and improve prevention of alien species, the following future works are recommended:

Prevention of introduction

- Review and update existing lists of prohibited species by carrying out good risk analysis.

  This exercise will properly identify potential IAS, potential biological and economical impacts, pathways of introduction, likelihood of entry, establishment and methods of prevention, introduction, establishment and spread.

- Review and update existing sanitary and phytosanitary measures or other relevant legislation, regulations and procedures to make them more effective in dealing with IAS.

  For example, Malaysia's present plant quarantine regulations do not require any permit for the importation of plants or plant parts for consumption, medicinal purposes, processing or manufacturing, nor for processed agricultural products, which are only subjected to inspection upon arrival. There is a very high risk of introducing IAS if loose regulations continue.

- Increase public awareness.

  The public by and large does not know or care about the dangers of introducing alien plant or animal species. Quarantine authorities are unable to check all cargo, passengers, or travelers at

all entry points. Harmful organisms also may hitchhike on a variety of goods. The presence of such organisms is usually difficult to detect. To counter these problems, cooperation of the public is required. The public must be informed about the dangers of IAS introductions, to be able to recognize major IAS, and to report them accordingly.

- Build capacity.

  The Department of Agriculture realizes the need for human resource development in specific fields such as inspection, detection, identification, sampling techniques, and treatment. Highly trained and efficient quarantine personnel, particularly those working at entry points will be able to contribute towards preventing entry of IAS into the country.

- Cooperate with international partners.

  Exporting and importing countries must comply with each other's sanitary and phytosanitary regulations when issuing phytosanitary certificates.

Containment and eradication

Containment and eradication aim to prevent further spread, and to remove the IAS from an infested area. It is relatively easy and effective when alien species are not yet established. Early detection and rapid response are imperative to contain and eradicate IAS. To achieve this objective, the following future steps are suggested:

- Target inspection and surveillance efforts

  Inspection and surveillance should be concentrated on high risk pests and proven pathways. It should also include highly susceptible areas with greater vulnerability.

- Develop contingency plans with a view to sharpening emergency action, and identify research, development and operational needs.

Control

Control measures are carried out when an IAS is permanently established and occurs widely. The sole objective of control is to reduce ecological damage and economic loss. The latter is more important as it affects the socio-economic well-being of the people most directly. To reduce the impacts caused by IAS, the following future steps are recommended:

- Increase research activities in all aspects of IAS management so that new control technologies can be developed;

- Intensify extension activities so that new control technologies can be effectively disseminated and adopted;

- Consider area-wide measures for control of widely spread invasive species.

Experts working on biological invasions

There are many agencies working on invasive alien organisms, namely the Department of Agriculture (DOA), Malaysian Agriculture Research and Development Institute (MARDI), Department of Veterinary Services, Department of Fishery and the Department of Forestry. They are responsible for research, overseeing technology transfer and extension. Other related agricultural agencies and universities (Table 2) assist in evaluation and technology development for IAS management. Plantation agencies also carry out research and development on specific crops and crop protection problems. However, up to now there are no agencies in the country working specifically on biological invasions. In the future it is hoped that IAS and their impacts will be taken more seriously either by government agencies or non-governmental organizations.

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Maldives

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Overview

The Republic of Maldives, consisting of a large number of coral islands, has been a trading crossroads of several maritime nations from as early as 2000 BC. The lack of local resources makes it necessary for this country to import virtually everything from furniture to fresh vegetables. With the expansion of tourism, fisheries, and agriculture, the demand for such products has increased, and inevitably so does the number of potential pathways and entry points for IAS. Already many alien invasive, insect, plant and disease species of agricultural importance have been identified from the country. Apart from the serious losses caused by these species, the Maldives is also concerned about potential impacts to its most important marine environment and to its biodiversity in general. As a country without proper management regimes for IAS, as well as a scattered territory that makes enforcement of quarantine regulations difficult, the Maldives is always at risk of IAS entering the country. Therefore, new IAS remain a pressing concern for the authorities responsible for environment conservation and other sectors of economic activity.

Introduction

The Republic of Maldives consists of 1,190 coral islands in a chain 820 km in length and 130 km at its widest point, set in an area of 90,000 sq. km. of the Indian Ocean, from the equator to 8˚ North. Only 197 of these islands are inhabited. India and Sri Lanka are its nearest neighbors, 600 km and 750 km north and northeast of the Maldives, respectively. The islands form 26 natural atolls, which for purposes of administration are grouped into 20 units, also called atolls. Most of the islands are small, few with a land area in excess of one sq. km. They are low-lying, with a mean elevation of 1.6 m above mean sea level.

It has a tropical climate, warm and humid, with two pronounced monsoon seasons. Daily temperatures vary little throughout the year. The annual mean temperature is 28ºC, with a maximum average of 32ºC and a minimum of 25ºC. Relative humidity ranges from 73% to 85%. Annual average rainfall in the

period 1995-2000 was 1,870 mm. Monthly variations in rainfall are significant, ranging from 12 mm in February to 250 mm in May. While there are occasional gales (on average 12 d/yr) and tropical thunderstorms (23 d/yr), Maldives falls outside the main areas of tropical cyclones.

The population of Maldives was estimated at 270,000 in 2000 and is scattered over the 197 inhabited islands. The remainder of the islands is uninhabited, although more than 70 of these islands have been developed as tourist resorts. Ninety percent of the inhabited islands have a population less than 1,000 and only four islands have more than 4,000 people. About 26% of the nation's population lives in Malé, the capital island. The population of Malé has almost doubled in the past decade, and is currently growing at around 5% per annum. The Maldivian population is young, with 45% under 15 years of age. Population growth rate of the country is high, averaging 3.2% in the period 1977-85, 3.4% in the period 1985-90, and about 2% in the period 1995-2000.

Tourism and fisheries are the main sectors of the Maldivian economy. The Gross Domestic Product (GDP) of Maldives should support a relatively robust per capita income and development (per capita GDP in 1999 was US$ 1910), but it is neither broad-based nor growing consistently, with the overall rate of growth in decline. Agriculture has the scope to pick up as an economic sector and its potential is currently being explored. The GDP contribution from tourism is consistent at more than 30%, while the fisheries sector has been declining from 7.8% of GDP in 1995 to 6.5% in 1999.

Status and impact of IAS

Major invasive pest species

Introduction of plant pathogenic microorganisms and insect pests is a concern to the Maldives, as a number of pests and diseases affect agricultural productivity. Influxes of planting materials, fruits and vegetables from neighboring countries without proper quarantine procedures can lead to rapid build-up of pests and diseases. Moreover, exporting countries are fully aware that the country lacks its own quarantine facilities, and dump products of low quality, infected with pests and diseases and treated with chemicals into the country. Unfortunately the isolated and scattered nature of the Maldives is no longer an effective barrier against the import of alien species into it. In the face of this build-up, more and more people have to rely on the use of hazardous pesticides for their control, which can contaminate the soil, harvested products, and the environment in general with pesticide residues. This is not a long-term solution and is likely to make the problem worse in the tiny island environment.

The following pests and diseases have been identified as harmful and have caused ecological and economic impacts in the country.

⇒ Citrus canker-causing bacterium, *Xanthomonas campestris* pv. *citri*

Invasion of an extremely aggressive strain of the bacterium during the 1980s killed majority of the local lime variety *Citrus aurantifolia*, which plays a major role in atoll agriculture. The aggressiveness of this strain resulted in cankerous devastation of the main branches of lime trees, subsequent defoliation and death. No feasible and ecologically acceptable chemical control method was identified. The consequence has been a six- to ten-fold increase in the price of lime fruit in local markets and an increasing dependence on imported fruit. Maldives was self sufficient in lime in the 1970s, but lime import has increased tremendously since 1988. Apart from these direct economic consequences, the reduction of locally produced limes is important because lime is one of the few sources of vitamin C in local diets. Lime also plays a central role in local cuisine. To date, rehabilitation programmes have not been successful and this variety of lime is threatened with extinction.

⇒ Stem borer, *Batocera rufomaculata* (De Geer)

Stem borer was introduced to the country in the early 1990s and was first observed attacking breadfruit trees. It is now to be found in every island of the Maldives. Larvae of this beetle bore into the stems and branches of the trees and kill it. Breadfruit was a common tree in every household in the Maldives in the 1990s, but is considered rare today. Due to the pest, an estimated 60% of breadfruit trees, an important seasonal staple food, have died. Symptoms of pest attack have also been observed from mango trees.

⇒ Spiralling whitefly, *Aleurodicus dispersus* (Russ)

In 1989, a heavy infestation of spiraling whitefly developed on various ornamental and fruit trees. The insect caused extensive damage to at least 24 host plant species, including economically important mango, papaya, guava, breadfruit, and banana trees. Two natural parasitoid enemies, *Encarsia haitensis* and *Encarsia* sp. were introduced from Fiji in 1990 and good control has been achieved. At present the pest is widespread in the Maldives but does not cause serious damage.

⇒ Giant African snail *Achatina fulica* (Ker)

The giant African snail was first observed in the early 1980s and became a serious pest of many crop species. Control was achieved using the flatworm *Platydemus manokwari* imported from Guam.

⇒ Rhinoceros beetle *Oryctes rhinoceros* (L.)

Although the beetle is believed to have originated from South-Southeast Asia, it is not native to the Maldives. It appears to have arrived sometime in the 1970s and severely affected coconut production. Until early 1980s, the rhinoceros beetle population in the Maldives was controlled by collection of adult beetles and by filling gaps in palm crowns with pebbles to prevent beetles attacking the growing points. In view of the local importance of coconut as a cash crop, FAO launched a biological control campaign, which resulted in introduction of the baculovirus as a control agent in 1984. This resulted in a 25% decline of coconut infestation, and a correspondent 10% yield increase within a year (Watson *et al.* 1995). Currently beetle infestation is on the rise again, causing poor yields.

⇒ Fringed nettle grub, *Darna nararia* (Moore)

This pest, introduced in late 1990s, damaged coconut palms within a very short period of time. Early control and management measures, assisted by the FAO, minimized the spread of the pest in the country.

Table 1. List of invasive insect species

Common name	**Scientific name**
American serpentine leaf miner	*Liriomyza trifolii*
assam or chili thrips	*Scirtothrips dorsalis*
banana aphid	*Pentalonia nigronervosa*
banana weevil borer	*Cosmopolites sordidus*
black citrus aphid	*Toxoptera aurantii*
black legume or cowpea aphid	*Aphis craccivora*
blue butterfly	*Euchrysops cnejus*
bread fruit borer	*Glyphodes sp nr stolalis*

bread fruit mealy bug	*Icerya aegyptica*
brown soft scale	*Coccus hesperidum*
cabbage web worm or centre grub	*Hellula undalis*
citrus black fly	*Aleurocanthus woglumi*
citrus leaf minor	*Phyllocnistis citrella*
citrus mealy bug	*Planococcus citri*
coconut hispid beetle	*Brontispa longissima*
coffee mealy bug	*Planococcus lilacinus*
cottony cushion scale	*Icerya purchasi*
diamond back moth	*Plutella xylostella*
fringed nettle grub	*Darna nararia*
glass house or black tea thrips	*Heliothrips haemorrhoidalis*
green peach aphids	*Myzus persicae*
green citrus aphid	*Aphis spiraecola*
green scale	*Coccus virdis*
gypsy moth	*Lymantria dispar*
lac insect	*Tachardina aurantiaca*
leucaena psyllid	*Heteropsylla cubana*
mango leaf hopper	*Idioscopus nitidulus*
mango stem borer	*Batocera rufomaculata*
mango thrips	*Thrips palmi*
melon and cotton aphid	*Aphis gossypii*
melon worm	*Diaphania hialinata*
nigra scale	*Parasaissetia nigra*
oriental citrus psyllid	*Diaphorina citri*
oriental scale	*Aonidiella orientalis*
phenacoccus scale	*Phenacoccus parvus*
pulvinaria scale	*Pulvinaria plygonato*
pumpkin beetle	*Aulacophora calva*
purple scale	*Lepidosaphes beckii*
pseudococcus scale	*Pseudococcus cruptys*
pseudococcus scale	*Pseudococcus elisiae*
red cotton bug	*Dysdercus koenigii*
red wax scale	*Ceroplastes rubens*
rhinoceros beetle	*Oryctes rhinoceros*
spiralling white fly	*Aleurodicus dispersus*
stellate scale	*Vinsonia stellifera*
sweet potato weevils	*Cylas formicarius*
sweet potato whitefly	*Bemisia tabaci*
tobacco thrips	*Frankliniella fusca*
tropical army worm or cluster caterpillar	*Spodoptera litura*
two-spotted spider mites	*Tetranychus urticae*
urbicola soft scale	*Pulvinaria urbicola*
white peach scale	*Pseudaulacaspis pentagona*

Introductions of *banana streak virus*, *bract mosaic virus* and bacterial pathogens *Erwinia* spp. are threatening banana production in the island ecosystem. Due to the malady of diseases attacking banana, farmers have abandoned banana cultivation. Banana was one of the most marketable crops in the country and accounted for the highest proportion of the farmers' income.

Table 2. List of invasive disease species

Plants attacked	Common name	Scientific name
annona		*Leptoxyphium fumago*
arecanut	leaf spot	*Mycosphaerella*
banana	sigatoka	*Mycosphaerella musicola*
banana	banana leaf and fruit spot	*Deightoneilla torusola*
banana	burrowing nematode	*Radopholus similis*
beans	phyllosticta leaf spot	*Phyllosticta*
beans	leaf spot	*Zygosporium gibbum*
betel leaf	leaf spot	*Mycosphaerella*
brassicas	alternaria leaf spot	*Alternaria brassicola*
bread fruit	leaf spot	*Mycosphaerella*
cassava	leaf curl	*Whitefly-Transmitted geminivirus*
chilli (capsicum)	anthracnose	*Colletotrichum gloesporioides*
chilli (capsicum)	leaf spot	*Pheoramularia capsicicola* ? (unknown species – ed.)
chilli (capsicum)	cercospora leaf spot	*Cercospora capsici*
citrus	melanose	*Diaporthe citri*
citrus	bacteril canker	*Xanthomonas campestris*
citrus	cercospora leaf spot	*Cercospora penzigii*
citrus	leaf spot	*Mycosphaerella*
citrus	anthracnose	*Colletrichum*
coconut	leaf spot	*Pestalotiopsis palmarum*
cucurbits	cercospora leaf spot	*Cercospora citrullina*
cucurbits	powdery mildew	*Sphaerotheca fussa*
cucurbits	cucumber mosaic	*Cucumber mosaic virus*
cucurbits	watermelon mosaic	*Watermelon mosaic virus*
egg plant	leaf blight and fruit rot	*Phomopsis vexans*
ground net	anthracnose	*Colletotrichum gloesporioides*
ground net	phomopsis	*Phomopsis pehenningii*
guava	leaf spot	*Phiomopsis psidi*
guava	anthracnose	*Colletotrichum gloesporioides*
mango	leaf spot	*Phoma*
mango	grey leaf spot	*Pestalotiopsis mangiferae*
mango	anthracnose	*Colletotrichum gloesporioides*
papaya	anthracnose	*Colletotrichum gloesporioides*
papaya	brown spot	*Corynespora cassicola*
papaya	black rot	*Phoma caricae-papayae*
papaya	root and fruit rot	*Phytophthora*
papaya	powdery mildew	*Sphaerotheca fussa*
pomegranate	leaf spot	*Pseudoccercospora punicae*
sapodilla	phomopsis leaf spot	*Phomopsis manikarae*
sorghum	leaf spot	*Phomopsis sorghicola*

stone apple	leaf spot	*Pseudocercospora jujubae*
stone apple	anthracnose	*Colletotrichum*
sweet potato	anthracnose	*Colletotrichum*
taro	dasheen mosaic	*Dasheen mosaic virus*
taro	phyllosticta spot	*Phyllosticta colocassicola*
taro	cladosporium spot	*Cladosporium colocasiae*
taro	leaf blight	*Phomopsis*
taro	leaf spot	*Phoma*
tomato	black leaf mould	*Pseudocercospora fuligena*
wax apple	leaf spot	*Asteromella* sp.

Invasive plant species

Numerous species of unknown origin are being introduced to the country as ornamental plants. The risk of such species becoming a pest is a real threat, but no such evidence has yet been recorded. There may be many species of invasive alien plants unidentified in the Maldives.

Table 3. List of known invasive plant species

Common name	**Scientific name**
lantana	*Lantana camara*
leafy spurge	*Eurphobia esula*
leucaena	*Leucaena leucocephala*
water hyacinth	*Eichhornia crassipes*
mile-a-minute weed	*Polygonum perfoliatum*

Marine species

Coral reef deterioration has been recorded in the Maldives on a few occasions. Some incidents are due to pests, and others to adverse environmental conditions. Widespread deterioration of reefs by increase of the crown-of-thorns starfish populations was observed during the 1970s and mid-1980s, and extensive coral bleaching events due to high temperature were recorded during the 1990s. However, there have not been any confirmed incidents of reef degradation by IAS.

Other

The presence of large numbers of insects can be extremely annoying and unhealthy to humans. The most irritating insect in this regard is gypsy moth, *Lymantria dispar*. Outbreaks of this insect occur almost twice a year throughout the country and have a number of social impacts. Gypsy moth larvae are a major nuisance when they defoliate shade and ornamental trees, crawl on around houses, leave debris from their feeding, and are therefore not tolerated in many island communities. The larvae have urticating hairs that cause skin irritations, which become seriously infected when infants and children are attacked.

Management programmes

Agricultural pests and diseases

It is important that alien pests and diseases are correctly identified and appropriate control measures used, while causing as little damage as possible to the host, environment, humans, and beneficial

organisms. Integrated pest and disease management is implemented to reduce occupational health risks with exposure of humans to toxic chemicals, and to safeguard the environment from further harmful effects.

The government of Maldives has taken measures to reduce the potential for entry and establishment of IAS. One such is the ban on importation of coconuts and vegetative parts of coconut palms to avoid importation of alien species which may threaten coconut production. Banana tissue culture production has been initiated to provide farmers with clean planting materials of banana. This will reduce the importation of banana planting material from elsewhere. Awareness campaigns on citrus canker control and rehabilitation of the local lime variety *Citrus aurantifolia* are currently underway. The government is also continuously lobbying for external assistance to strengthen the plant quarantine services of the Maldives. Establishment of such a system is vital to protect the Maldives' fragile, terrestrial and marine ecosystems.

Marine environment

In view of the importance of the marine environment to the very existence of the coral reefs and therefore the country's economy, the government of Maldives follows a cautious policy with regard to the introduction of alien species. All development projects, including those of marine aquaculture, are required by law to have environmental impact assessments, and projects are approved based on the outcomes of these assessments. The protection and management of the marine environment reflects collaborative efforts of many local, regional, and international agencies. There are existing environment and fisheries laws, and several research, management and awareness programmes being undertaken to protect the marine environment in the short and long term. Such programmes include reef monitoring, protected areas management, protected species management and reef resources management.

Biodiversity

Loss of biodiversity due to aggressive IAS has been recognized as a threat to the fragile ecosystems of Maldives. Maldives became a Party to the Convention on Biological Diversity on 28th October 1992, being among the first Asian countries to ratify this convention. The first *National Biodiversity Strategy and Action Plan* (NBSAP) of the Maldives was formulated in 2001. It has highlighted a number of management actions in relation to IAS. The NBSAP will serve as a guide for protection, management and sustainable use of biological resources, and has recognized the importance of controlling and managing IAS for conserving the country's marine and terrestrial biodiversity. Hence, the NBSAP recommended establishing proper sanitary and phytosanitary measures. The NBSAP specifically recommended the following actions to be taken at the national level to manage IAS:

- Formulate quarantine and other regulations to control IAS import including pests and diseases;
- Adopt risk assessment techniques developed by international organizations for identification, entry, establishment and control of potentially harmful species;
- Establish suitable quarantine facilities at points of entry;
- *Establish appropriate measures for conservation of local biological diversity when transferring species from one locality to another within the country.*

List of government organisations that can be potentially involved in management of IAS

Ministry of Fisheries, Agriculture and Marine Resources
Ghaazee Building
Malé, Maldives
Tel: (960) 32 2625 Fax: (960) 326558
Email: agri@fishagri.gov.mv

Marine Research Center
Ministry of Fisheries, Agriculture and Marine Resources
Malé, Maldives
Tel: (960) 32 2242 Fax: (960) 322509
Email: marine@fishagri.gov.mv

Ministry of Home Affairs, Housing and Environment
Huravee Building
Malé, Maldives
Tel: (960) 32 17 52 Fax: (960) 32 47 39

Environment Research Center
Ministry of Home Affairs, Housing and Environment
Malé, Maldives
Tel: (960) 33 59 49 Fax: (960) 33 59 53
Email: erc@environemnt.gov.mv, erc@dhivehinet.net.mv

Port Health Section, Department of Public Health
Boduthakurufaanu Magu
Malé, Maldives
Tel: (960) 32 39 63 Fax: (960) 32 19 24

Maldives Ports Authority
Boduthakurufaanu Magu
Malé, Maldives
Tel: (960) 32 93 39 Fax: (960) 32 52 92
Email: maldport@dhivehinet.net.mv

Conclusions

As a nation at the trading crossroads of several maritime nations, with a lack of local resources and regulatory capacity, the Maldives is extremely vulnerable to IAS. New IAS remain a pressing concern for authorities responsible for environmental conservation and other economic sectors.

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Nepal

Sharing experiences from agricultural and forestry sectors

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Overview

The kingdom of Nepal lies in a transition zone between the eastern and western Himalayas, enjoying tropical to arctic climates within a small area with a sharp altitudinal variation (60 m – 8848 m). Such a diverse climatic and physiographic setting offers opportunities for great variability in floristic composition. Nepal has not been an exception to the world-wide free exchange of seeds of agricultural and forestry crops and the import and export of various plant species. Some of these alien species have contributed positively to food and timber production, while others have become invasive. Very limited research has been carried out on IAS and their impacts in the country. Currently, management of alien IAS is done mainly through on-farm management by farmers and through advice and training from agricultural extension programmes. IAS work is a new field in Nepal, and has yet to be planned and started in a systematic manner. In this regard, issues that need to be considered urgently are: exploration and management of uses of already existing IAS; no introductions to be done in the future without prior information and evaluation so that further deterioration of agricultural, forest and other ecosystems is prevented. Nepal should commence more work on IAS urgently.

Introduction

The kingdom of Nepal is a country of great ecological, biological and cultural diversity. Lying in a transition zone between the eastern and western Himalayas, it has climates ranging from tropical to arctic within a small area over a sharp altitudinal gradient. This diverse climatic and physiographic setting has generated great floristic diversity, as illustrated by Nepal's 118 different ecosystems, 75 vegetation types and 35 forest types (NBS, 2002). Of its total area, 39.6% is under forest and about 21% under agriculture. Around 80% of the Nepalese people are employed in the agriculture sector, using both indigenous and alien crop varieties. Nepal has less than 0.1% of the earth's land area but about 6% of the earth's bryophytes, 3% of its pteridophytes, and over 7000 species of flowering plants (NBS, 2002). Over 200 species of commercially important medicinal and aromatic plants, 400 species of agro-horticultural crops, over 60 species of wild edible fruit crops, and over 300 species of orchids are also found in Nepal.

Throughout its history, the country has freely exchanged seeds of agricultural and forestry crops, and imported and exported various plant species. Some of Nepal's alien species have contributed positively to food and timber production, as in several part of the world, whereas a few of them have invaded ecosystems, especially when not managed properly. A species considered invasive in one agro-

ecological system might be considered useful in another area, if used for an economic purpose with proper management. It is therefore often difficult to generalise and categorise alien IAS, especially in a country like Nepal where very limited research has been done in this regard. Therefore, it is important to identify both IAS and their habitat simultaneously.

A consultative country workshop was organised recently in Kathmandu by IUCN-Nepal to discuss and inventory IAS (IUCN, 2001). This meeting developed a common definition of IAS as "organisms that have been moved from their native habitat to a new location where they cause significant harm to the environment, economic systems and or human health" (Tiwari & Siwakoti, 2001). Some progress has been made since then to develop inventory methods and gather information on IAS from different representative ecological sites in the country. Based on available information, this paper shares some of the experiences on identification, management efforts and future possibilities for better management of IAS in Nepal.

IAS currently recorded from Nepal

Based on discussions and field experience, following species have been identified as IAS from different areas of Nepal.

Table 1. Invasive alien species recorded from Nepal.

Name	**Local name**	**Impacted ecosystems***
Phalaris minor canary grass	ragate, gahukomama, ledai, thulo matte	croplands (wheat) in Tarai, inner Tarai, mid-hills
Orobanche spp. bromme rape	thokara	croplands (mustard), forests, Tarai, inner Tarai
Eichhornia crassipes water hyacinth	jal kumbho	wetland sites in Tarai, Siwalik, mid-hills
Eupatorium adenophorum crofton weed	banmara/kalojhar	forests, shrublands, grasslands, croplands in Tarai, Siwalik, mid-hills
Chromolaena (Eupatorium) odorata	banmara	forests, shrublands, grasslands in Tarai, Siwalik
Lantana camara lantana	masinu kande	forests, wastelands, shrublands from Tarai to mid-hills
Ipomoea carnea	besaram	moist wastelands in Tarai and Siwalik
Parthenium hysterophorus ragweed		grasslands in Tarai, Siwalik along roadsides
Ageratum conyzoides	gandhe jhar	grasslands and crop fields in Tarai to mid-hills
Alternanthera philoxeroides alligator weed	patpate	crops, irrigation channels, moist places
Xanthium strumarium cocklebur	bhede kuro	crops, wastelands, grasslands in Tarai to mid hills
Polygonum perfoliatum		shrublands, wastelands in the Kathmandu valley
Mikania micrantha	banmara	forests, grasslands, wastelands in Tarai and Siwalik
Hyptis suaveolens		forests, croplands in Tarai, Siwalik

**Editors' note: 'Tarai' is a narrow strip of flat land at about 150 m altitude along Nepal's southern border, including several 'dun' (inner Tarai) valleys north of the first range of hills, with many Indian cultural influences. Previously covered in thick forest, they have been cleared for agriculture. 'Siwalik' is a Nepalese term for hilly land.*

Existing programmes on IAS

Management of IAS is done mainly through farm management, and through advice and training from agricultural extension programmes. Farmers are trained to manage invasive weeds and shrubs, of which most are removed from the farm, but many are used for several purposes such as livestock fodder/forage, fuelwood, and as hedges. *Orobanche* spp. in mustard fields and *Phalaris minor* in wheatfields are some common examples of farmer management of IAS in Nepal. No chemicals are used against such weeds in Nepal. Likewise, forest-based IAS such as *Eupatorium* spp. are removed from forest plantations, shrublands and enrichment plantation sites, and are used as goat fodder, animal bedding, green manure or green fuel. Occasionally, IAS such as *Eichhornia* are removed from lakes by local communities to preserve the aesthetic value of these water bodies. Up to now, there are no specific programmes launched by the government, on a priority basis, for management of IAS in this country.

List of potential organisations in the management of IAS in Nepal

The following organisations are relevant for future programmes in management of IAS.

- Ministry of Agriculture and Cooperatives
- Ministry of Forests and Soil Conservation
- Ministry of Environment and Population
- Ministry of Science and Technology
- Royal Nepal Academy of Science and Technology (RONAST)
- Department of Agriculture Services
- Nepal Agricultural Research Council (NARC)
- Institute of Agriculture and Animal Sciences - Tribhuban University
- Nepal Aayurved Campus, Naradevi
- Department of Forests
- Department of National Parks and Wildlife Conservation
- Department of Soil Conservation and Watershed Management
- Department of Plant Resources
- Department of Forestry Research and Survey
- Institute of Forestry, Tribhuban University
- IUCN – Nepal
- WWF -- Nepal
- International Centre for Integrated Mountain Development (ICIMOD)

Future priorities

Since there has not been adequate attention given to management of IAS in the country, the first and foremost task on this subject is identification and assessment of IAS, their habitats, nature of invasion, and indigenous management practices, if any. Secondly, there should be work on participatory management and use of IAS to encourage control of invasions. Strengthening plant quarantine facilities would focus adequate attention to IAS, from the beginning before invasions take place on a large scale. More research is required to understand the impact of such species, and awareness should be created among all stakeholders. A sensitisation workshop on IAS issues is urgently needed at the national level. This workshop should then create a forum for further discussion and planning of better management of IAS in the country.

List of currently engaged/ potential experts

There is no one individual or a single organisation fully engaged on prevention of entry, establishment and management of IAS in Nepal. However, the following scientists/experts have been involved in some respects, and therefore are suggested for further interaction on this subject. This list does not however undervalue the available expertise and experience of others from various governmental and non-governmental organisations and universities in Nepal, not included here.

- Mr. Sagendra Tiwari, Programme Coordinator, IUCN-Nepal
- Dr. Dharma Dangol, TU, IAAS, Rampur
- Prof. R. P. Chaudhary, Central Dept. of Botany, TU, Kirtipur
- Dr. Krishna Chandra Paudel, Ministry of Forestry and Soil Conservation
- Mr. Prachanda Shrestha, Ministry of Industries and Commerce
- Dr. Jagat Devi Ranjit, Crop Science Division, NARC, Khumaltar
- Dr. T.B. Shrestha, Royal Nepal Academy
- Dr. K. R. Rajbhandari, Dept. of Plant Resources, Kathmandu
- Dr. N. K. Bhattarai, Dept. of Plant Resources, Kathmandu
- representatives of the Directorate of Crops, Dept. of Agriculture, Kathmandu

Conclusions

Being a new field of research and development in Nepal, work on IAS is yet to be planned and started in a systematic manner. In this regard, activities that need to be done urgently are:

⇒ exploration and management of uses of already existing IAS;
⇒ prohibition of further species introductions without prior information and evaluation, so that further deterioration of agricultural, forest and other ecosystems and environment is prevented.

It is now a suitable time for beginning more work on IAS in Nepal.

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Pakistan

Sharing experiences from the forestry sector

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Overview

Pakistan is a country with contrasting features. A large part of the country is in an arid and semi-arid zone, which falls into a hydrological unit drained by the Indus river system. Agriculture accounts for the largest sector of the national economy. Like many countries, Pakistan has had many introductions of IAS, but not much research on those species or their impacts. Vascular plants are the best known group of species, and are thus known to include several high-impact IAS. A comprehensive catalogue of other organisms including animals, algae, fungi, and bacteria is not available. Thus, nothing can be said with certainty about the number of IAS in these groups. Some of the well known harmful animal introductions include fish and shellfish for aquaculture and aquaria, and insect pests of agriculture and horticulture. Fortunately, the magnitude of IAS in Pakistan is not as great as in some other countries, but unfortunately, there is virtually no awareness of this important issue among the general public, policy-makers, and even most natural resource managers. There is no legislation that deals specifically with IAS. Pakistan has taken the important step of establishing the IAS Specialist Group-Pakistan (ISSGP) at the national level, with support from IUCN and CABI-BioScience. This group will work to increase awareness of problems created by IAS, among the public at large, policy makers, and other stakeholders, and identify increasing problems of IAS. Prevention is recommended as the prime method for management of IAS, as control and eradication are technically difficult and expensive. This paper lists many specific recommendations for addressing IAS issues in Pakistan.

Introduction

Pakistan is a sub-tropical country lying between 24° and 37°N latitudes and 61° and 75°E longitudes. Stretching over 2500 km from the Arabian Sea to the Himalayas, Pakistan's landscape presents contrasting features: the bulk of the country is in an arid and semi-arid zone, which falls into a hydrological unit drained by the Indus river system. Agriculture is the largest sector of the national economy (see Table 1 in Annex I for land use data), contributing about 25% of the GDP and providing employment to more than half of the labour force.

Forests and forestry in Pakistan have a rather chequered history, as the country is situated on the route of many human migrations and invasions that took place over thousands of years. The destruction of forests was inevitable, due to increasing pressure of settlers and their livestock. Scientific management of forests was started just over a century ago, laying emphasis on conservation, and at the time of independence in 1947, forests in Pakistan had already been exploited to a considerable extent. Pakistan is the seventh most populous country in the world, with a density of 163 persons per square kilometre and an estimated population (including Azad and Kashmir) of 143.6 million, 67.5% being rural and 32.5% urban.

Forest resources

Out of a total land area of 88 million ha, 4.2 million ha (4.8%) are covered with forests. These forests are mainly state owned and managed. It is estimated that about one-third of the forest area consists of production (commercial) forests, and the rest of protection forests.

Table 1. The distribution of forest area (000 ha) by forest type.

Forest type	Dense forests	Sparse forests	Other forests	Total
coniferous	138	1775	–	1913
riverine	115	58	–	173
irrigated plantations	55	48	–	103
mangrove forests	–	120	87	207
linear plantings	16	–	–	16
scrub forests	–	1191	–	1191
farmlands trees	466	–	–	466
misc. plantings	–	–	–	155
Total	790	3192	87	4224

Source: Forestry Sector Master Plan Report, 1993

Forest types

The main forest types are coniferous forests, riverine forests, irrigated plantations, mangrove forests, farmlands, linear plantings, and miscellaneous plantings. These are described in greater detail below.

⇒ *Coniferous forests*

These forests occur at an elevation of 1500 to 3500 m and are found in moist temperate, dry temperate and sub-tropical zones. They are located in the upland watersheds. They protect fragile mountain ecosystems and provide water for irrigated agriculture and power generation. Main species of conifers growing naturally include *Cedrus deodara, Abies pindrow, Pinus wallichiana, Picea smithiana, Pinus gerardiana, Juniperus excelsa* and *Pinus roxburghii* with broad-leaved associates such as *Quercus iticana* and *Acer indica.* These forests are the main source of construction timber, large quantities of fuelwood, resin, and grazing for millions of goats, sheep and cattle.

⇒ *Riverine forests*

These forests are situated on the land lying between the banks of river Indus and its tributaries and the protective embankments. The main species include *Acacia nilotica, Populus eupharatica, Tamarix dioica* and *Prosopis specigera.* These forests are of high economic value as they provide timber for coal mining and the furniture industry, and large quantities of fuelwood.

⇒ *Irrigated plantations*

These are man-made forests, planted after clearing the indigenous thorn forests in areas where canal water was available for irrigation. The main purpose is fuelwood production, but small quantities of timber are also produced for sports goods and furniture. The main species are *Dalbergia sissoo, Morus alba, Acacia nilotica, Eucalyptus* sp., *Bombax ceiba* and *Melia azadarach.* Recently, fast-growing species like hybrid poplar and *Eucalyptus* have also been planted in these plantations.

⇒ *Scrub forests*

These forests grow in the foothills and vary in density from a perfect canopy in well protected areas to scattered single trees or groups on dry sites. Main species include *Acacia modesta* and *Olea cuspidata.*

⇒ *Mangrove forests*

The Indus delta on the Arabian seacoast near Karachi supports valuable mangrove forests. The main species found here include *Avicennia officinalis, Ceripos tagal* and *Bruguiera conjugata.* These are mainly protective forests, but provide some grazing and fuelwood to coastal people.

⇒ *Farmlands*

Farmers in Pakistan have grown trees on their lands for a long time to meet their needs for fuelwood and small timber. Recently they have started growing trees commercially. They are the main source of fuelwood and hardwood timber supplies in the country. The species composition of growing stock of farmlands is: *Dalbergia sissoo* (22%), *Acacia nilotica* (14%), mango (4%), mulberry (3%), poplar (3%), *Eucalyptus* (1%) and other species.

⇒ *Linear plantings*

These consist of trees raised along railroads, roads and canals. The main species are *Dalbergia sissoo* and *Acacia nilotica,* which have a mainly protective and aesthetic value.

⇒ *Miscellaneous plantings*

These are plantations established on private lands in upland watersheds under World Food Programme activities in the 1970s and 1980s.

Major policies and programmes relevant to IAS issues

The National Conservation Strategy

This was formulated in order to protect and conserve the environment on a long-term basis. Its main objectives are to conserve natural resources, foster sustainable development and improve efficiency in the use and management of resources. Its three operating principles are: enlisting public participation in development and management; merging environment and economics in decision making; and focusing on durable improvement in the quality of life. Its main long-term goals include the following:

- Effective soil conservation in all rain-fed and upland croplands;
- Protection, management and maintenance of all watersheds through an integrated approach by 2060;
- Organized communities in all villages in all upland watersheds by 2060;
- The most suitable 10% of poor forest and rangeland under 10% tree cover and managed on a sustained yield basis by 2060;
- Setting up 35 national parks covering all ecosystems;
- Conservation of all species on the endangered list.

National Forest Policy 2001

This policy covers renewable natural resources of Pakistan such as forests, watersheds, rangelands, wildlife, biodiversity and their habitats, and seeks to foster their sustainable development. Elements of the policy relevant to IAS and biodiversity management include: improvement of institutions; policies for critical ecosystems; scientific management of irrigated plantations; preservation of relict and unique forests; supporting the implementation of treaties such as CBD, CITES, Ramsar, and CMS; conservation of threatened species of wildlife and their habitats; management of rangelands and desert ecosystems, and encouraging a participatory approach to growing trees and fodders on farms.

Forestry Sector Master Plan (1993-2018)

To realize the policy objectives of meeting national needs for forest products while ensuring environmental protection and improvement, a 25-year forestry development plan was put in place. Its main components are:

- Protection of watersheds and soil conservation;
- Wood production programmes;
- Intensification of management of coniferous forests;
- Planting in Federally Administered Tribal Areas (FATAs);
- Managing irrigated plantations;
- Managing riverine forests;
- Amenity plantings;
- Planting non-forest public lands;
- Ecosystems and biodiversity programmes;
- Strengthening institutions.

Successful implementation of the Forestry Sector Master Plan is expected to increase forest area from the current 4.2 million ha to 8.6 million ha (9.1% of total land area), raise the sustainable supplies of wood, reduce soil erosion from watersheds, and create new job opportunities in planting of trees, harvesting, processing and distribution of wood.

Present status of alien IAS in Pakistan

The problem

Not much research on alien species or on the impacts of IAS has been done up to now. The meager studies undertaken so far list 700 alien species of vascular plants, and 4500 indigenous species (Khatoon & Ali, 1999). Of these, six can be regarded as high-impact invasives (*Broussonetia papyrifera, Prosopis juliflora, Eichhornia crassipes, Salvinia molesta, Parthenium hysterophorus,* and *Lantana camara*). *Eucalyptus camaldulensis* is another example of an IAS in farm forestry in the mountainous area of Malakand-Dir, known for its aggressiveness and release of allelo-chemicals into the environment (Hussain et al., 2000 and Saleh, 2002). A comprehensive catalogue of other organisms (even of indigenous species), including animals, algae, fungi, bacteria, etc. is not available. Therefore, nothing can be said with certainty about the number of IAS in these groups. The known intentional introductions of animal species include sheep and cows from Australia and New Zealand, finfish (e.g. silver carp, China grass carp, tilapia, rainbow trout) and shellfish for aquaculture and aquaria, and Australian bees for apiculture. Of these introductions, tilapia has escaped from aquaculture and has established on its own in many wetlands in Sindh (Q.M. Ali, pers. comm.), while China grass carp, introduced in the 1970s into Haleji Lake for controlling weeds, has reportedly deprived the native

herbivorous fish of their food. Accidental introductions include insect pests of agriculture (e.g. American bollworm, *Heliothis armigera*), and pests of horticulture.

Fortunately, the magnitude of IAS in Pakistan is not as great as in some other countries, but unfortunately, there is virtually no awareness of this important issue among the general public, policy-makers, and even among most of the forest department personnel. While most of the introduced plant species date back to the colonial era, new intentional introductions (both authorized and unauthorized) go on, unabated. Nursery owners frequently import seeds and propagules of ornamental plants, while most officially sanctioned tree-plantation drives involve alien species. The following brief account illustrates the magnitude of this absence of awareness. Most irrigated plantations in Pakistan have cultivated a sizeable area with *Eucalyptus camaldulensis*, and planting campaigns are in progress to plant eucalypts under farm forestry projects, and annual planting programmes. In 1999, the monsoon tree-plantation drive in Sindh was launched by planting *Lignum vitae* (*Guaicum officinale* - a native of South America), while the spring tree plantation of 2000 was launched by planting *Eucalyptus*. In 1998, a former Chief Minister had pledged to plant 8 million *Eucalyptus* trees in Sindh. In August 1999, an anti-pollution rally organized by various government departments and NGOs planted 1000 saplings of *Eucalyptus*, neem, and *Conocarpus* around Keenjhar Lake to "save the lake" (The DAWN newspaper, 29 August 1999). What they did not know was that they had actually damaged the lake surroundings by planting these alien species. Like *Melaleuca*, *Eucalyptus* spp. are also capable of lowering the water-table due to fast growth and excessive transpiration, having allelopathic effects on indigenous vegetation, and containing highly inflammable volatile oil contents in leaves, which can trigger forest fires in hot and dry season. The large-scale introduction of *Eucalyptus* has not only changed the characteristic landscape of Sindh, Punjab, the North Western Frontier Province (NWFP) and Balochistan, but in the long run will have detrimental effects on water resources as well. Both *Eucalyptus* and neem harbour fruit-eating bats, which are a potential serious threat to orchards, and also may serve as seed-dispersal agents for the alien trees. Although these species have not so far become, strictly speaking, invasive, they may become so in the future, given their large scale plantings, and repeated introductions coupled with targeted destruction of native vegetation, in the name of "cleaning" the environment. Awareness campaigns on the importance of indigenous flora and the dangers of IAS are needed in Pakistan, more than anywhere else in the world.

Legislation/ prevention measures

There is no legislation that deals specifically with IAS. The *Biodiversity Action Plan* (BAP) of Pakistan deals with this problem very superficially. Action 6.6 of the BAP reads: "Take measures to control IAS of fauna and flora, and to prevent further introductions." The Quarantine Department checks plant and animal species being imported only for any pests or pathogens accompanying them. There is no provision to check the possible ecological impact of imported species.

National efforts

The first-ever workshop on IAS in Pakistan was held on 17 September 1999 at Islamabad, jointly organized by IUCN-Pakistan and CABI-Bioscience. While discussing the issue, participants agreed on the following definition: "IAS are those species which are alien, and which because of their aggressive and/or gregarious nature, become an agent of change, reducing the number, relative abundance and Importance Value Index (IVI) of the native species, and thereby threatening the overall biodiversity in a given region." The participants also wished to prepare a list of well-known IAS. Since comprehensive knowledge is hitherto available only for vascular plants (in the *Flora of Pakistan*), the workshop deliberations were concerned with plants only; but it was decided that other groups (animal, algae, fungi, bacteria) should be dealt with later.

The workshop recommended that an institution should be identified to give certificates of clearance before the introduction of species. This institution should be advised by a panel of experts belonging to various fields of biology, especially plant and animal taxonomists, agriculturists and foresters. The workshop also resolved to open a Pakistani Chapter of ISSG (IUCN/SSC IAS Specialist Group), named the IAS Specialists Group- Pakistan (ISSGP). It was formed at the national level with support from IUCN and CABI, and will highlight in a brochure to be produced by them, the problems created by IAS. For increasing awareness of the public at large, stakeholders and policy makers, ISSGP will issue newsletters, bulletins and identify the increasing problems of IAS in the country.

Recommendations for addressing IAS

Preventive methods for managing IAS should be the priority in Pakistan, because control and eradication are technically difficult and expensive. Specific recommendations are as follows:

- As a first step, commission a technical review of IAS occurrence in Pakistan.
- Enhance local expertise for managing IAS, and train staff in the preparation of contingency plans for coping with invasions.
- Prepare a black list of IAS in Pakistan.
- Strengthen and build capacity of the quarantine department for identification of IAS in the country. This is necessary because of increasing trade and travel.
- Prepare contingency plans for priority areas in Pakistan.
- Restore highly degraded and threatened native ecosystems, e.g. riparian forests in Sindh, and sub-tropical forest in Swat, Hazara, and Azad Jammu & Kashmir.
- Carry out biological control of alien aquatic and terrestrial weeds, as that appears to be the only long-term answer to those problems.
- Support education and awareness as an important method in management of IAS. The government through relevant institutions, departments, television and the print media, should organise public fora to discuss important issues on pests.
- Initiate research projects to investigate the impacts of IAS on biodiversity, tourism, agriculture, livestock production, etc.
- Initiate conservation projects aimed at conserving and restoring biodiversity, habitats and ecosystems that are threatened by IAS.
- Develop legislation to discourage introduction of IAS, because there is at present no check on the introduction of such species.
- Facilitate close coordination and collaboration between quarantine and plant protection departments.
- Revise laws, to encompass linkages between animal, plant and bio-safety issues.
- Include prevention and management of IAS in forest and agriculture policies.

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Annex 1. Annotated list of preliminarily recognized invasive alien plants in Pakistan.

Scientific name and family	English & (local) names	Origin	History of introduction*	Comments	Worst-affected areas
Broussonetia papyrifera Moraceae	paper mulberry (gul toot)	SE Asia	1880 at Saharanpur, by 1924 to Lahore via irrig. channels; now most problematic IAP in N Pakistan	serious human allergen; spread by invasive alien house crows	Islamabad-Rawalpindi, from Lahore to Peshawar and N Pakistan.
Prosopis juliflora Fabaceae	mesquite (kikari)	W Indies, SW USA, Mexico	1878 by British for afforesting deserts of Sindh, southern Punjab	serious and well established, toxic metabolites	riparian forest of *Acacia nilotica* in Sindh
Eichhornia crassipes Pontederiaceae	water hyacinth (gul-e-bakauli)	Amazon basin	unknown	serious and well established, diverse impacts	Sindh and Punjab and in the water bodies of Pakistan
Salvinia molesta Salviniaceae	Kariba weed water fern, salvinia (unavailable)	S America	recently introduced, source unknown. First noted on Keenjhar Lake, Thatta in late 1990s	aggressive and well established, diverse impacts	in wetlands and irrigation channels of Thatta
Lantana camara Verbenaceae	lantana (panch phuli)	Americas	unknown, thought to be an old introduction	aggressive and well established, diverse impacts	in and around Islamabad
Parthenium hysterophorus Compositae	white top, congress grass, carrot grass (unavailable)	Meso-America	unknown. First noted in 1956 from Poona, India and in 1980s from Pakistan	aggressive competitor with biodiversity and health impacts	Islamabad and environs, where it is highly invasive
Cannabis sativa Cannabaceae	hemp (bhang)	Central, W Asia	unknown, thought to be an ancient introduction	moderate invasive, human allergen	invades waste areas, northern Punjab and NWFP
Pistia stratiotes Araceae	water cabbage (jal kumbi)	Old, new world tropics	unknown, thought to be an old introduction	well established, diverse impacts	water reservoirs, the edges of large lakes
Ipomoea carnea Convolvulaceae	railway creeper (railway creeper)	tropical America	unknown, thought to be an old introduction (colonial)	fast growing competitor	southern Sindh & Indus delta
Emex spinosa Polygonaceae / Plantaginaceae	prickly dock (kafir kanda)	Mediterranean region	unknown, recently accidentally introduced from Afghanistan and Iran	spreading fast, nuisance weed	cooler parts of the country
Galium aparine Rubiaceae	catchweed bedstraw (galium)	Europe	unknown, thought to be an old introduction	agricultural weed with diverse impacts	distributed in Pakistan form plains to 12000 feet
Xanthium strumarium Compositae	cocklebur (puth kando)	New world	unknown, thought to be an old introduction, now widely distributed		most parts of Pakistan and rangelands to 8000 feet
Leucaena leucocephala Fabaceae	leucaena, ipil ipil (as adopted locally)	Meso-America	introduced in late 1800s by British	aggressive weed with livestock health impacts	parts of Pakistan, e.g. Punjab
Lolium temulentum Gramineae/ Poaceae	darnel, rye grass (Dhanak)	Mediterranean region	unknown, thought to be an old introduction	moderate invasive at present	throughout Pakistan from plains to 2000 feet.
Robinia pseudoacacia Papilionaceae	black locust (Robinia)	USA, SE & Central America	Unknown; planted by Forestry Dept for fodder, fuelwood, soil stability	Well established, may threaten biodiversity	plains & hills of Pakistan
Ailanthus altissima Simarubaceae	tree of heaven (asmani)	China, Japan	Unknown; naturalized in Pakistan over large areas	Aggressive invader, may threaten biodiv.	Malakand, Huzara, Chitral, Gilgit & Baluchistan
Eucalyptus camaldulensis Myrtaceae	red river gum (sufeda, lachi)	Australia	1860 in undivided India by British; 1911 Botanical Gardens of Lahore; 1962 used in reclamation of damp areas	Well established and used in plantations – diverse impacts	throughout Pakistan

** Information mainly from Parker (1924)*

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- Quarantine Department, Ministry of Food, Agricultural and Livestock, Government of Pakistan
- Plant Protection Department, Ministry of Food, Agricultural and Livestock, Government of Pakistan
- Pakistan Forest Institute, Peshawar
- NWFP-Agriculture University, Peshawar
- Botany Departments of all universities of Pakistan
- Centre for Agricultural Bio-science International, Regional Centre, Rawalpindi
- International Union for conservation of Nature-The World Conservation Union, Peshawar
- World Wide Fund (WWF) – Pakistan
- Forest Departments of Punjab, Sindh, NWFP, Balochistan, Northern Areas and Azad Jammu & Kashmir
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Overview

In the Philippines more than 475 plant species, mainly from the Malayan region, have been introduced during historical times. A high percentage of alien species has also been introduced within the past 400 years, including many of American origin (Merrill, 1912). Intentional and accidental introductions of alien species have been done for economic reasons, until they are observed to be invasive and causing economic and environmental damage. This situation has arisen as bio-safety measures and environmental impacts of alien species were not considered prior to introduction. There is a lack of data on IAS in the Philippines, as there have been only a few research studies conducted on impacts and management of IAS. The list of known alien IAS at present includes terrestrial and aquatic weeds, trees, insects, fish, and amphibians. The Philippines has commenced work to address IAS at a national level, but much more remains to be done on this theme. Inventorying all alien species and establishing country and regional hubs for coordination of work are some of the strategies recommended.

Introduction

The Philippines is a contracting party to the Convention on Biological Diversity (CBD). In fulfillment of its obligations, the country undertook an assessment of its biodiversity through a grant from United Nations Environment Programme (UNEP) to the Department of Environment and Natural Resources. Based on this comprehensive assessment of the current status of the country's biodiversity, problems, threats, issues and gaps were identified (DENR-UNEP, 1997). One of the threats to indigenous species is IAS, recognized in Article 8h of the CBD: "*Prevent the introduction of, control, or eradicate those alien IAS which threaten ecosystem, habitat and species*".

Alien species as defined in the CBD include any species which are introduced into new habitats, and usually these are invasive or aggressive species. Human actions are the primary means of IAS introductions, usually for economic reasons, and without a careful consideration of the full costs involved. Therefore, the global economy fosters the spread of alien IAS.

In the Philippines, more than 475 plant species have been introduced in ancient times, mainly from the Malayan region. A high percentage of alien species has been introduced within the past 400 years, including many of American origin (Merrill, 1912). About 225 species are found only under cultivation for food, and are not reported to cause economic or environmental harm. Intentional and accidental introductions of alien species happen for economic reasons and are often only later observed to be

invasive and cause economic and environmental damage. This arises when biosafety measures and environmental impacts of foreign species are not considered before their introduction.

This report presents the available meagre information stemming from a few research studies that were conducted on the impacts and management of introduced IAS in the Philippines.

Table 1. List of IAS and their effects

I. Terrestrial plants		
Species	**Common name**	**Comments**
Chromolaena odorata	haganoy weed	considered a harmful weed in grassland ecosystem, outgrows or prevents establishment of other species, e.g. *Imperata*, reduces feed available for livestock and other species
Lantana camara	large leaf lantana	widely grown as an ornamental shrub; established weed in pasture lands
Mikania micrantha	Chinese creeper/ mile-a-minute	vigorous and rampant growth; damages or kills other plants by cutting out light and smothering them
Gmelina arborea		host of the insect pests, *Ozola minor* and *Attacus* sp.
Acacia mangium		host of insect pest, *Anoplophora luciphor*
Eucalyptus camaldulensis		host of an unidentified termite species
Swietenia macrophylla		host of the insect pest, *Zeuzera coffeae*
Dipterocarpus grandiflorus		host of the insect pest, *Dryocoetiops laevis*
Leucaena leucocephala		host of the insect pest, *Heteropsylla cubana*
Toona ciliata		host of an unidentified weevil
II. Terrestrial invertebrates		
Pheidole megacephala	big-headed ant	highly invasive, serious threat to biodiversity, displaces native invertebrate fauna, harbours phytophagous insects that reduce crop productivity, domestic pest
Solenopsis geminata	fire ant	grave threat to conservation, invading native communities and impacting on many or all species
Heteropsylla cubana	jumping plant lice	introduced by typhoons in late 1980s, affects almost 100% of standing *Leucaena leucocephala* crop country-wide
Aleurodicus dispersus	spiralling whitefly	accidentally introduced by importation of ornamental kalanchoe in 1970s, now affects vegetable/ornamental crops
Liriomyza spp.	leafminers	accidentally introduced through importation of ornamental chrysanthemums; major pest of potato and ornamentals
Pseudococcus sp.	mealybug	accidentally introduced in hybrid coconut planting materials in late 1990s; affects coconut in Northern Palawan
Scotinophora coarctata	rice black bug	introduced by vessels entering Palawan, Mindanao; major pest of rice in Mindanao and Leyte Provinces
Oncydium sp.	orchid virus	brought in through orchid importation in the late1970s
Globodera rostochiensis	potato cyst nematode	accidentally introduced in potato planting materials; now infesting potato in the area of Baguio
III. Aquatic plants		
Salvinia molesta	water fern	former problem weed in Iloilo, especially in irrigated rice where it competes for nutrients and water; clogs waterways
Eichhornia crassipes	water hyacinth	rapidly invading Laguna Lake, reduces phytoplankton growth and food to fish; clogs waterways
IV. Aquatic animals		
Clarias batrachus	Thai catfish	introduced to Luzon from Thailand to boost aquaculture, displaced native *Clarias macrocephalus*; not commercialized due to tough flesh; now widespread
Clarias gariepinus	African catfish	not yet considered invasive, but on "watch list"
Hypostomus plecostomus	South American catfish	not yet considered invasive, but on "watch list"; introduced in 1990s by ornamental fish industry; escaped from breeding ponds into Laguna de Bay/nearby rivers; competes for food

Pomacea canaliculata	golden apple snail	displaced native kuhol, *Pila luzonica;* considered major pest of rice seedlings; deliberately imported as protein source
Glossogobius giurus and *Hypseleotries agilis*	white goby and eleotrid	caused extinction of most of the 15 cyprinids of Lanao Lake, Mindinao
Micropterus salmoides	black bass	caused disappearance of original fish of Caliraya L., Laguna
Bufo marinus	marine toad	reduced populations of several native frogs from Dumaguete City, Negros; prolific; nuisance in large numbers
Rana catesbiana	American bullfrog	has potential to displace native frogs
Rana tigrina	leopard frog	has potential to displace native frogs

List of existing national IAS programmes (management efforts and awareness campaigns)

Existing programmes

- Implementation of quarantine regulations;
- Implementation of the Philippine Policy on Biodiversity;
- Implementation of the Guidelines on Planned Release to the Environment of Genetically Modified Organisms and Potentially Harmful Exotic Species;
- Biological control of *Chromolaena odorata* by gall fly;
- Management of rice black bug through monitoring, mass production and field application of *Metarhizium,* an ongoing programme of the Department of Agriculture, Philippines;
- Implementation of the Wildlife Act.

Actions already taken

- Seminar-Workshop on Biodiversity and Management of Alien Invasive Species in the Philippines, May 22-23, 2001; Quezon City, Philippines; Sponsored by Parks and Wildlife Bureau, Department of Environment and Natural Resources (PAWB-DENR) and ASEAN Regional Centre for Biodiversity Conservation (ARCBC).
- Exhibit on Biodiversity Management of Alien IAS, May 22-23, 2001; Quezon City, Philippines; Sponsored by PAWB-DENR and ARCBC.

List of organizations potentially involved with the management of IAS in the Philippines

Government agencies

- Department of Environment and Natural Resources
- Department of Agriculture
- Department of Tourism
- Department of Trade and Industry
- Department of Foreign Affairs
- Department of Transportation
- Department of Interior and Local Government
- Department of Science and Technology.

Non-government organizations

- NGOs for Integrated Protected Areas, Inc.
- Civil Society Counterpart Council for Sustainable Development
- Southeast Asia Regional Institute for Community Education
- Philippine Sustainable Development Network Foundation Incorporated.

Priorities for future work and strategies for management and policy recommendations

⇒ Preparation of inventory/status report of each alien species (invasive and non-invasive)
⇒ Preparation of database of all alien species
⇒ Preparation of a database of management strategies
⇒ Networking between those involved in IAS issues, including:
  - ➢ Establishment of a country hub specific for monitoring and management of alien species;
  - ➢ Establishment of a regional hub as IAS regional data repository and knowledge management from and for member countries, and fund sourcing for all IAS activities including research and development.

⇒ Enforcement of quarantine regulations
⇒ Enhancement of policies and other regulations related to IAS
⇒ Monitoring of IAS
⇒ Research and development
⇒ Enhancement of public awareness
⇒ Encouragement of advocacy campaigns on taking action against IAS.

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Overview

This paper reviews the status of IAS in Singapore based on published data and includes an updated preliminary list of confirmed IAS. As the country is a major hub of trade, travel and tourism in Asia, most of the introductions so far have been deliberate it is expected that there will be more such in the future. At least 17 species of alien plants and 55 species of alien animals, a small fraction of those currently present, may be considered harmful in Singapore. The destruction of natural habitats in Singapore due to urbanization has caused greater damage to indigenous biota than the replacement threat brought by IAS. However, as there is no single agency to co-ordinate issues of IAS, and with economic activities set to grow in the country, unless high levels of vigilance are maintained, there can be a serious impacts due to IAS in Singapore.

Introduction

IAS are defined here as introduced or alien species that create havoc or damage either by partial displacement or complete replacement of native species in pristine or naturally disturbed habitats. In our presentation, we distinguish IAS from alien or foreign species that have been introduced but survive thus far, only in man-made habitats, such as gardens, roadsides, city parks, parking lots, and open wastelands around human settlements.

Singapore has a long history of introduction of foreign plants and animals. The island's location at the centre of major air and shipping routes has inevitably resulted in the accidental or deliberate introduction of numerous plant and animal species, not to mention micro-organisms and fungi (Ng et al. 1993). As Singapore strives to become a world class cosmopolitan city and centre of tourism in Southeast Asia, it is expected that the deliberate introduction of organisms will continue if only to enrich the quality of life and the living environment. This is especially true in the case of species with decorative or food potential. The water hyacinth (*Eichhornia crassipes*) and the water spangle (*Salvinia molesta*), which were introduced as ornamental plants, escaped from cultivation and caused environmental problems in several reservoirs and river systems in Singapore in the 1970s and 1980s (Wee & Corlett 1986). In the same way, the rock or feral pigeon, *Columba livia*, the Javan myna, *Acridotheres javanicus,* and the house crow, *Corvus splendens*, were all probably introduced as a result of the pet trade over the last two hundred years. They have become well adapted to the urban environment and have at one time or another caused health concerns due to their large populations located in the vicinity of human populations.

Terrestrial flora

The status of alien plant species was discussed by Corlett (1988) and Turner and Tan (1992), while that of alien animals in Singapore was reviewed by Chou and Lam (1989) and Ng et al. (1993). For plants, more than half of the introduced species are originally from the tropical New World, followed by Asia, and lastly, Australia and Africa (Appendix 1). However, among plant groups, the focus has been solely on seed plants. It is only now that we have information about alien pteridophytes and mosses that have become established in Singapore (Wee 1997; Tan & Tan 2000; Tan & Buck 2002).

Terrestrial and freshwater fauna

There is good taxonomic knowledge about alien mammals, birds, reptiles, amphibians, freshwater fish and decapod crustaceans. Apart from rats, few alien mammals have established themselves in Singapore, in contrast to 72 alien bird (Lim & Gardner, 1997; Appendix 1). Their effect on what little is left of the original flora and fauna of Singapore has, however, not been studied. The majority of naturalized birds in Singapore originate from the Asian subcontinent, with only a few species from Australia and Africa (Appendix 1). Many are cage escapees that have become adapted to the now largely urban environment of Singapore. Naturalized reptiles from the pet trade include the red-eared terrapin *Trachemys scripta* from North America (Anonymous, 2002), striped keelback *Xenochrophis vittatus* from Indonesia, and changeable lizard *Calotes versicolor* from Indochina (K.K.P. Lim, pers. comm.). The painted bullfrog *Kaloula pulchra* from Indochina and American bullfrog *Rana catesbeiana* from the USA are now common in residential areas and reservoirs, respectively.

Others have been introduced in connection with religious and cultural practices, such as the Malayan box turtle *Cuora amboinensis* and black marsh turtle *Siebenrockiella crassicollis*. These are the common kinds of turtles that can be purchased in Singapore and released free by local Buddhist followers on Vesak Day. The majority of alien freshwater fishes resident in Singapore are a result of the ornamental fish trade. Of a total of 58 alien teleost fish species recorded from Singapore thus far (K.K.P. Lim, pers. comm.), about half of these species are from Asia, while species from Central and South America comprise a further 33% of the total number of exotic species. Most of the remaining species are African cichlids. Two species of freshwater prawns (*Macrobrachium lanchesteri* from Thailand and *M. nipponense* from East Asia) are now established in freshwater streams in Singapore, but again, their impact on native inhabitants has not been elucidated. The giant African snail, *Achatina fulica*, and the African tilapia, *Oreochromis mossambicus*, both now with well-established populations throughout Singapore, were deliberately introduced during the Second World War as a potential source of protein. Other invertebrate groups such as protozoa, platyhelminthes, nematodes and insects remain poorly documented and their presence (or absence) is not immediately known.

Marine flora and fauna

In the estuarine environment, two exotic bivalve species have established themselves in Singapore in recent years. The Caribbean bivalve, *Mytilopsis sallei* (Dreissenidae), is found in large numbers mostly along the walls and floor of tidal monsoon canals, forming mats of several kilometers long in some cases (Tan and Morton, submitted). This bivalve is closely related to the notorious Asian zebra mussel, *Dreissena polymorpha*, which has invaded and caused havoc in waterways in the North American continent. Not surprisingly, *Mytilopsis* has already established itself in various Asian ports including Japan, Taiwan, Hong Kong, Thailand, Fiji, Darwin and India. In Singapore, *Mytilopsis* occurs together with native byssate bivalves, *Isognomon ephippium* (Isognomonidae) and *Musculista senhausia* (Mytilidae), which are common in mangroves but have found the monsoon canals to be suitable habitats as well. It is interesting to note, however, that *Mytilopsis* is rare in the mangroves, and it remains to be seen if this bivalve can be classified as "invasive" as defined in this review. The other exotic bivalve is

the Indian mussel, *Brachidontes striatulus* (Mytilidae), which, although not as widespread as *Mytilopsis*, is also found in monsoon canals (Morton and Tan, submitted). It is likely that these species traveled to Singapore as adults attached to ships' hulls, or as larvae in ballast water.

Discussion

Thus far, most of the introduced species in Singapore are from freshwater and terrestrial habitats (Ng et al. 1993; Corlett 1988), and by comparison, little is known about marine IAS. Similarly, the taxonomy of many groups of indigenous organisms, particularly the marine algae, plankton and invertebrates, remains problematic and poorly documented. It is obvious that this incomplete knowledge of native flora and fauna has impeded the positive identification of alien species. This is a major hurdle for Southeast Asian countries in general where inherent biological diversity is extremely high but taxonomic expertise is either highly inadequate or lacking. Additionally, the available literatures pertains only to the history and listing of alien species of plants and animals, but not about the ecological impacts on indigenous species of these aggressive invaders.

However, not all alien species in Singapore are invasive, threatening the survival of local counterparts. Cursory observations suggest that a great majority cannot even survive outside of human intervention. Of the more than 2000 introduced plant species grown in Singapore, about 136 species have become naturalized on their own capability (Corlett 1988). Only a small fraction of these, such as *Adiatum latifolium, Clidemia hirta, Spathodea campanulata, Dioscorea sansibarensis* and *Thunbergia grandiflora*, have been reported to actually invade the primary and old secondary forests, and/or inhibit the regeneration of secondary forest (Turner & Tan 1992). The explanation has been attributed to the fact that many of the introduced species are sun-loving plants and require a nutrient-rich soil for their establishment and expansion. Apparently, in Singapore many local forest plant species have evolved over the millennia to become well adapted to the closed tropical forest condition and, therefore, are resistant to foreign aggression, as long as the remaining forest or original vegetation is not disturbed further by human activities (Teo et al., 2003). In other words, it would appear that the continuous human disturbance facilitates the local spread of invasive alien plant species.

Interestingly, Ng et al. (1993) came to the same conclusion in their assessment of the invasiveness of freshwater fishes and prawns introduced via the aquarium trade in recent years. According to them, these alien species have not affected significantly the fauna in pristine forested streams. Of a total of 58 alien fish species known to occur in Singapore, about 22 species have established populations. The likely reason for the poor penetration of alien species into native habitats is that more than 80% of the native species are forest species. They are adapted to living in acid water characteristic of the streams found inside the remaining forests, whereas the introduced ones were found to prefer more neutral or alkaline waters. In fact, their study showed that more than 50% of the indigenous fauna have become extinct today due to forest clearance.

The poor performance of invasive plant and animal species at present in Singapore does not mean that serious invasions will not occur in the future. Perpetual alertness and constant monitoring are needed to prevent the problem from becoming an environmental crisis. This is particularly relevant in the case of micro-organisms, which have direct relevance for ballast water management.

Fortunately or unfortunately, because of the lack of serious invasions on the island, the government of Singapore has taken a light attitude in managing this potential ecological problem. As a signatory of CITES, the government has concentrated its effort on the implementation of the treaty by controlling the illegal trading of plant and animal species listed as endangered and prohibited under the CITES regulatory programme. Likewise, with the decrease of agricultural activities in the country, the

government also has relaxed its monitoring of the introduction of the many officially listed crop plant diseases and soil nematodes.

Currently there are four government agencies tasked with the function of monitoring the movement of alien species, namely, the Agri-food and Veterinary Authority of Singapore (AVA), the National Parks Board (NParks), the Maritime and Port Authority of Singapore (MPA) and the recently formed National Environment Agency (NEA). As the names of these offices imply, each is given the responsibility to monitor alien species in a defined and separated area, such as the agriculture and food sector, forest and park administration, and other types of environment management. There is a lack of comprehensive legislature governing the introduction of "friendly" alien species and the prevention of "harmful" species. Likewise, there is no single umbrella office to oversee and coordinate the various offices should there be a need at the national level to confront a developing environmental crisis due to the outbreak aggression of an invasive plant or animal species.

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Appendix 1. List of established alien species in Singapore*

Scientific name	Common name	Family	Origin
I. PLANTS			
Ferns			
Adiatum latifolium		Adiantaceae	tropical America
Pityrogramma calomelanos	silver fern	Pteridaceae	America
Salvinia molesta	water spangle	Salviniaceae	tropical America
Angiosperms			
Acacia auriculiformis		Leguminosae	Australia/ PNG
Albizia falcataria		Leguminosae	Moluccas
Mimosa pigra		Leguminosae	South America
Eichhornia crassipes	water hyacinth	Pontederiaceae	tropical America
Lantana camara	lantana	Verbenaceae	tropical America
Manihot glaziovii	tapioca	Euphorbiacease	tropical America
Mikania micrantha		Asteraceae	tropical America
Peperomia pellucida		Piperaceae	tropical America
Pilea microphylla		Urticaceae	tropical America
Dioscorea sansibarensis		Dioscoreaceae	Africa
Spathodea campanulata		Bignoniaceae	Africa
Thunbergia grandiflora		Acanthaceae	SE Asia
Wikstroemia ridleyi		Thymeliaceae	Asia
Clidemia hirta		Melastomaceae	tropical America
II. ANIMALS			
Mollusca: Gastropoda			
Pomacea canaliculata	apple snail	Ampullariidae	South America
Taia polyzonata		Viviparidae	Thailand?
Achatina fulica	giant African snail	Achatinidae	Africa
Mollusca: Bivalvia			
Pseudodon vondembuschianus		Unionidae	Indonesia
Brachidontes striatulus		Mytilidae	Bay of Bengal
Mytilopsis sallei		Dreissenidae	Central America, Caribbean
Arthropoda: Crustacea			
Macrobrachium lanchesteri	riceland prawn	Palaemonidae	Thailand
Macrobrachium nipponense	Japanese freshwater prawn	Palaemonidae	East Asia
Cherax quadricarinatus	red-clawed crayfish	Parastacidae	Australia

Pisces: Teleostei			
Rasbora borapetensis	red-tailed rasbora	Cyprinidae	Thailand
Esomus metallicus	Siamese flying barb	Cyprinidae	Thailand
Puntius binotatus	two-spotted barb	Cyprinidae	Southeast Asia
Puntius partipentazona	Malayan tiger barb	Cyprinidae	Thailand, West Malaysia
Puntius tetrazona	Sumatran tiger barb	Cyprinidae	Sumatra
Puntius semifasciolatus	green barb	Cyprinidae	China
Liposarcus pardalis	armoured sucking catfish	Loricariidae	South America
Poecilia reticulata	guppy	Poeciliidae	South America
Poecilia sphenops	green molly	Poeciliidae	Central America
Gambusia affinis	mosquito fish	Poeciliidae	Eastern USA
Oxyeleotris marmorata	marbled goby, soon hock	Eleotridae	Southeast Asia
Rhinogobius giurinus	pond goby	Gobiidae	China
Channa micropeltes	toman, giant snakehead	Channidae	Southeast Asia
Parambassis siamensis	glass perch	Chandidae	Thailand and West Malaysia
Oreochromis mossambicus	tilapia	Cichlidae	East Africa
Tilapia buttikoferi	hornet tilapia	Cichlidae	Africa
Cichla ocellaris	peacock bass	Cichlidae	South America
Cichlasoma urophthalmus	cichlid	Cichlidae	Central America
Nandopsis managuense	jaguar cichlid	Cichlidae	Central America
Nandopsis festae	red devil	Cichlidae	Central America
Veija synspillum	cichlid	Cichlidae	Central America
Etroplus suratensis	green chromide	Cichlidae	India, Sri Lanka
Amphibia			
Kaloula pulchra	painted bullfrog	Microhylidae	Indochina,Thailand
Reptilia			
Trachemys scripta elegans	red-eared slider, terrapin	Emydidae	USA
Xenochrophis vittatus	striped keelback	Colubridae	Sumatra and Java
Calotes versicolor	changeable lizard	Agamidae	India, Indochina
Aves			
Dendrocygna arcuata	wandering whistling-duck	Dendrocygnidae	Philippines to east
Eos bornea	red lory	Psittacidae	South Maluku
Cacatua sulphurea	yellow-crested cockatoo	Psittacidae	Eastern Indonesia
Cacatua goffini	Tanimbar cockatoo	Psittacidae	Tanimbar Id, Indonesia
Psittacula krameri	rose-ringed parakeet	Psittacidae	Africa to Myanmar
Psittacula alexandri	red-breasted parakeet	Psittacidae	India, Myanmar, Indochina
Columba livia Gmelin	rock pigeon	Columbidae	Eurasia?
Streptopelia tranquebarica	red-collared dove	Columbidae	South Asia
Threskiornis melanocephalus	black-headed ibis	Threskiornithidae	Pakistan to Thailand
Corvus splendens	house crow	Corvidae	Iran to Thailand
Sturnus melanopterus	black-winged starling	Sturnidae	Java to Lombok
Acridotheres javanicus	Javan myna	Sturnidae	Java to Sulawesi
Acridotheres cristatellus	crested myna	Sturnidae	S China to Myanmar
Pycnonotus jocosus	red-whiskered bulbul	Pycnonotidae	S China, India to SE Asia
Zosterops palpebrosus	oriental white-eye	Zosteropidae	W to SE Asia
Garrulax leucolophus	white-crested laughing thrush	Sylviidae	N India to SW China
Garrulax canorus	hwa-mei	Sylviidae	S China to Indochina
Passer domesticus	house sparrow	Passeridae	Europe to Asia
Lonchura leucogastroides	Javan munia	Passeridae	Sumatra to Lombok
Padda oryzivora	Java sparrow	Passeridae	Java, Bali

*principally compiled from Corlett (1988) (plants), Ng et al. (1993) (freshwater animals), Lever (1996) (fishes) and Lim & Gardner (1997) (birds). The geographic distribution of bird species follows Sibley & Monroe (1990).

Sri Lanka

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Overview

Sri Lanka, along with the Western Ghats region of India, has been recognized as one of the twenty-five biodiversity hotspots of the world. Sri Lanka has recognized the importance of IAS as a major threat to its native biodiversity and agriculture, especially as it is a small island nation. Alien species have invaded, and continue to invade, natural and agricultural ecosystems of the country. In the currently available lists of IAS from Sri Lanka, in comparison with alien invasive plants relatively few alien invasive fauna are present. This reflects the greater amount of information available on invasive plants. Exchange of seed material between countries, especially through botanical gardens, has been one of the major modes of deliberate introduction of alien plants into the country. Several pieces of legislation have been enacted in Sri Lanka since the early 20th century to safeguard indigenous plants and animals against these threats. However, a more comprehensive policy and legal framework is required for effective prevention and management of IAS. In this regard, the Ministry of Environment and Natural Resources, Government of Sri Lanka has placed great emphasis on awareness programmes for the general public which highlight adverse impacts of IAS, and also expects to put in place a national action plan to control IAS. To overcome further detrimental effects on agricultural and natural ecosystems, the policy makers of Sri Lanka must put management of IAS high on their list of national resource management priorities.

Introduction

Sri Lanka is an island 880 km north of the equator off the southern tip of India, and measures 435 km at its longest and 225 km at its broadest. The total land area is approximately 62,705 sq. km., 20% of which consists of natural forests, while another 40% is cultivated land. It has a well-defined central mountainous region with peaks as high as 2,524 meters, surrounded by plains stretching down to the ocean. Being close to the equator, the island has a tropical climate, with a mean annual temperature of 26-28 ºC in the low country and 14-24 ºC in the central mountainous region. The agricultural sector

contributes about 18% of the GDP of the country (Central Bank Report 2002). The major exports of the country include finished clothing, gems, tea, rubber, and coconut. About 46% of the labour force is in agriculture, 29% in industry and 19% in the services.

Despite its relatively small size, Sri Lanka possesses a high level of biodiversity which is supported by its wide topographic and climatic variation. A noteworthy feature of Sri Lanka's biodiversity is the remarkably high proportion of endemic species among its flora and fauna: 23% of the flowering plants and 16% of the mammals in the island are endemic. Sri Lanka along with India's Western Ghats region has been recognized as one of the twenty-five top biodiversity hotspots of the world.

The global impact of IAS has been recognized by the CBD, which calls for the control and monitoring of alien species that threaten ecosystems, habitats and species. Sri Lanka is a party to the CBD (signed on 05th June, 1992 and ratified on 23rd March, 1994), and has recognized the importance of IAS as a major threat to native biodiversity, especially as it is a small island nation. Alien species are invading our natural and agricultural ecosystems, causing tremendous damage. These IAS get into our ecosystems by various means. Fast-growing alien plants encroach from populations established outside target ecosystems; invasive alien plants escape cultivation and become agricultural pests, infest lawns as weeds, displace native plant species, reduce wildlife habitat, and most likely alter ecosystem processes. Across Sri Lanka, as around the world, IAS have become one of the most serious threats to native species, natural communities, and ecosystem processes.

The importance of understanding the impact of IAS in Sri Lanka has been accepted recently. Several alien species are reported to be spreading at alarming rates, threatening natural and agricultural ecosystems of the country. Sri Lanka has considerable experience, where deliberate introduction of alien plants has finally resulted in them becoming invasive or weedy. It should be noted that plants that are now invasive or weedy, once appeared to be non-invasive when their populations were small, or when they occupied only habitats influenced by people.

IAS in Sri Lanka

Human intervention has facilitated the spread of several invasive plant species within Sri Lanka (Marambe et al., 2001a, 2001b). A recently compiled list of invasive alien flora and fauna, and recently reported agriculturally important alien pests are given in Tables 1-3. Relatively little information is available on the spread of invasive alien fauna. Exchange of seed material between countries, especially through botanical gardens of respective countries, has been one of the major modes of deliberate introduction of alien plant species into the country or an ecosystem. Over-introduction is one of the common features of this kind of entry.

Considerable efforts have been made by Sri Lankan scientists in the past to overcome threats from IAS on the some of the ecosystems of the country. Legislative measures, mechanical and physical control, and biological control were some of the strategies adopted and are still being used to manage IAS populations in the country. Development of sound management strategies based on ecological principles, co-ordination between line agencies, and human resource development should be priority areas for successful management programmes for IAS in Sri Lanka.

Invasive alien flora

Salvinia, *Salvinia molesta*, was introduced to Sri Lanka in the late 1930's due to scientific interest, but appears to have escaped and is currently a major aquatic weed, choking irrigation canals and water bodies and also invading rice fields in the northwestern province of the island nation. Although there is no accurate information on the degree of infestation, in 1988 about 8000 ha of rice fields were reported

to be infested with this weed (Amarasinghe & Ekneligoda, 1997). Due to the detrimental effects of this aquatic plant on agricultural ecosystems, *Salvinia molesta* came under strict control of the Plant Protection Ordinance in Sri Lanka. An eradication campaign was initiated in 1957 with community participation, but was abandoned in 1964 due to financial difficulties. Although biological control with an insect, *Cyrtobagus salviniae*, was successful in several areas in the country, it has failed in cooler climates and in areas with low water levels and high temperatures (Amarasinghe & Ekneligoda, 1997).

Table 1. Invasive alien plants reported from Sri Lanka

Species	Distribution	Affected habitats/ecosystems
Alstonia macrophylla	sub-montane zone	degraded forests, forest edge
Alternanthera philoxeroides	up- / low-country wet zones	fallow fields, marshy/riparian areas
Annona glabra	lowland wet zone	coastal lagoons, marches
Cestrum aurantium	montane zone	montane forests
Clidemia hirta	sub-montane wet zone	rain forests
Clusia rosea	sub-montane zone	rock outcrop forests
Colocasia esculenta	island-wide	wetlands, marshes
Cuscuta spp.	island-wide	wastelands, agricultural land
Dillenia suffructicosa	low-country wet zone	forest edge, open scrublands
Eichhornia crassipes	island-wide	reservoirs, ponds, marshes, streams
Eupatorium riparium	montane zone	montane forests, roadsides
Hydrilla verticillata	island-wide	streams, canals, marches
Lantana camara	island-wide	scrubland, degraded open forests
Leucaena leucocephala	dry and intermediate zones	dry-mixed evergreen forests
Miconia calvescens	sub-montane zone	forest edge
Mimosa invisa	island-wide	wastelands, agricultural lands
Mimosa pigra	dry and intermediate zones	river banks, fallow fields, irrigation canals
Myroxylon balsamum	wet and intermediate zones	sub-montane forests
Opuntia stricta	arid zone	thorn scrublands
Panicum maximum	island-wide	wastelands, agricultural lands
Parthenium hysterophorus	dry and intermediate zones	wastelands, irrigation canals
Pennisetum polystachyon	dry and intermediate zones	wastelands
Prosopis juliflora	arid zone	thorn scrublands
Pteridium aquilinium	montane zone	grasslands, riparian areas
Salvinia molesta	island-wide	reservoirs, ponds, marshes, streams, paddy fields
Tithonia diversifolia	wet and intermediate zones	wastelands, roadsides
Ulex europeaus	montane zone	montane forests, wet pathana grasslands
Wedelia trilobata	wet and intermediate zones	wastelands, roadsides

Source: Updated from Marambe et al. (2001b)

Eichhornia crassipes (water hyacinth) was introduced to Sri Lanka due to its horticultural value. However, two years after its deliberate introduction to the country, a Water Hyacinth Ordinance was enacted in 1907, which indicated the understanding of the long-term detrimental effects of invasive alien plants by the policy makers of Sri Lanka, more than 90 years ago. However, despite this effort, *E. crassipes* is a major aquatic weed in the country today, choking water bodies and negatively impacting irrigation schemes. Biological control techniques to manage water hyacinth populations were introduced to Sri Lanka in the 1980s, but these two agents *Neochetina eichhorniae* and *N. bruchi* have not performed as expected. Thus, mechanical removal is used to clear infested water bodies, which in turn has resulted in its spread due to contamination of the machinery used for this purpose (Marambe, 1999).

Mimosa pigra (giant sensitive plant) was recently identified from Sri Lanka, growing luxuriantly in the riverbanks of the Mahaweli River, which is a major source of irrigation water that supports agricultural crops in the country. It is also known from other areas in the central province, spreading at an alarming rate (Amarasinghe & Marambe, 1997; Marambe et al., 2001a). Although the pathway of entry of this plant into the country is not well understood, it is widely believed that this invasive alien plant was intentionally introduced to protect the river banks. The major mechanisms of spread of *Mimosa pigra* into other parts of the country have been identified as irrigation water, machinery, river sand used for construction purposes, and lopping branches with mature pods, as a result of the use of the stems of the plant as fuelwood by people (Marambe, 2000).

Parthenium hysterophorus (congress weed) is among the latest recorded invasive alien plants. The weed has occupied about 150 ha of fallow, agricultural land in the hilly region, some parts of the Kandy district of the central province, and the Vavuniya district of the northern province (Jayasuriya, 2001). The weed was first believed to have entered the northeast of the country in the late 1980s, through goats imported from India by the Indian Peace-Keeping Force (IPKF). Information available at present also indicates that seeds of *P. hysterophorus* have entered along with seeds of onion and chillies imported from India. This is a classic example of the result of open trade policies, with poor quarantine measures, helping the spread of IAS. The weed has now been declared a noxious weed by the Ministry of Agriculture, and an extraordinary gazette notification issued on 20th December 2000 (No. 1163/23) indicates regulations for prevention of further entry, spread and its eradication under the Plant protection Act No. 35 of 1999.

Lantana camara (lantana), a plant introduced to Sri Lanka in 1826 due its horticultural value and attraction of butterflies, has been purposely established in sugarcane growing areas in the southern province of Sri Lanka to protect cane plants from elephant damage. The plant is now distributed island-wide and is commonly found in dense stands along roadsides and in abandoned lands (Marambe, 1999, 2000, Marambe et al., 2001c,d). It can be observed growing in Uda Walawe National Park, one of the major elephant sanctuaries in southern Sri Lanka, significantly reducing the grazing areas for elephants.

Myroxylon balsamum was introduced to the Central Province as a windbreak species and has now developed into monospecific stands covering a large extent of Udawattekele Nature Reserve in the Kandy district (Wedatanthri & Hitinayake, 1999; Hitinayake et al., 2000; Pushpakumara et al., 2000).

Ulex europaeus (gorse weed), presently confined to Horton Plains National Park in the central hill region of Sri Lanka, is found to affect some habitats of this park. Although efforts have been undertaken by many organizations, comprising environmentalists and schoolchildren, to eradicate this weed, their attempts were aborted due to the fact that endemic lizards and amphibians seek protection from their natural enemies in this thorny plant (Bambaradeniya et al., 2001).

Prosopis juliflora (mesquite) is a species introduced to the Hambantota district in the southern province of Sri Lanka in the early 1950s to improve its salt-affected soils, and as a form of ground cover (Algama and Seneviratne, 2000). The species has now become a serious invasive and is a threat in Bundala National Park, a Ramsar wetland site. The weed, which has caused major habitat changes in the national park, has deprived large mammals such as elephants of important habitats. The species is also spreading in the seashore areas of the Bundala area, thereby reducing the area for wading birds (Bambaradeniya et al., 2001).

Alternanthera philoxeroides (alligator weed) was an accidental introduction to the country and has spread rapidly due to human interventions. The weed, easily misidentified as a commonly cultivated leafy vegetable, *Alternanthera sessilis*, has invaded more than 200 ha of land in the southern province

of Sri Lanka. The Department of Agriculture has now taken measures to eradicate the plant from cultivated land with the assistance of the farming community (Department of Agriculture, 2000).

Leucaena leucocephala (leucaena) was a deliberate introduction as a multipurpose tree species in the early 1980s. Although a psyllid bug infestation destroyed the *Leucaena* cultivation initially, resistant cultivars of this species have escaped and are spreading at an alarming rate in the southern province.

Anredera cordifolia (a perennial vine), was recently identified as an invasive weed in tea plantations of Sri Lanka. It is reported to be a deliberate introduction to tea plantations, as the tubers of this plant are edible.

Cultivation of *Tithonia diversifolia* in Sri Lanka was encouraged by scientists and academics as a major green manure crop in the early 1980s. However, the weed has now escaped from cultivated sites and is colonizing roadsides and abandoned lands in most parts of the country.

Invasive alien fauna

Bubalus bubalis (feral buffalo) had been imported to Sri Lanka from South and Southeast Asia since historical times, for animal husbandry. Buffaloes were once heavily used in rice cultivation for land preparation. During the fallow period of rice cultivation, rural farmers release domestic buffaloes to the wild and recapture them during the next cultivating season. This has resulted in the domestic buffalo interbreeding with native wild buffaloes, leading to large herds of feral buffaloes that have become a serious threat to native ungulates in forest ecosystems throughout the country (see Marambe et al., 2001b).

Hypostomus plecostomus (tank cleaner), a species imported to Sri Lanka by the ornamental fish industry, has been observed to attach itself by its ventral sucker to the bodies of larger fish. When it detaches, the slime layer covering the outside of the fish which acts as a protective covering is also removed, making the host susceptible to diseases (Bambaradeniya et al., 2001).

Chitala chitala (clown knife fish), a well-known large, voracious carnivore, feeds on slow-moving indigenous fish. The species is spreading rapidly in streams, rivers, ponds and marshes of the wet zone, thus threatening species of endemic fish in these ecosystems (Bambaradeniya et al., 2001).

Sarotherodon mossambicus (tilapia), introduced to Sri Lankan aquatic ecosystems as source of protein, shows non-selective feeding habits and prolific breeding, enabling it to colonize reservoirs, small tanks, and slow-flowing rivers. Thus, this IAS has replaced some of the native inhabitant fish such as *Labeo porcellus* and *L. dussumieri* (Bambaradeniya et al., 2001).

Table 2. Invasive alien animals reported from Sri Lanka

Species	**Distribution**	**Affected habitats/ecosystem**
Oncorhynchus mykiss	montane zone	streams
Chitala chitala	lowland wet zone	reservoirs, ponds, slow-flowing rivers, marshes
Hypostomus plecostomus	lowland wet zone	reservoirs, ponds, slow-flowing rivers, marshes
Poecilia reticulata	island-wide	reservoirs, ponds, slow-flowing rivers, marshes, streams
Sarotherodon mossambicus	island-wide	reservoirs, slow-flowing rivers, marshes
Trichogaster pectoralis	dry and intermediate zones	reservoirs, marshes, streams
Achatina fulica	island-wide	natural and managed terrestrial habitats
Laevicaulis alte	island-wide	natural and managed terrestrial habitats

Semperula maculata	island-wide	natural and managed terrestrial habitats
Semperula sp.	island-wide	natural and managed terrestrial habitats
Rattus rattus	island-wide	natural and managed terrestrial habitats
Bubalus bubalis	island-wide	forests
Pomacea bridgesi	low-/mid-country wet zone	reservoirs, irrigation canals

Source: Marambe et al. (2001b)

Legislative provisions in relation to control and management of IAS

Control and management of IAS need a strategic approach that encompasses prevention, eradication, control and containment. Prevention is the cheapest and most preferred option. The threat from IAS to local species, particularly in the sphere of agriculture, has been well understood for a long time. Several pieces of legislation have been enacted in Sri Lanka since the early 20th century to safeguard plants and animals in local habitats against these threats. The following is a list of this legislation.

⇒ *Water Hyacinth Ordinance* – this ordinance, declared in 1909, restricts the introduction and dissemination of this aquatic weed in Sri Lanka. This act could be expanded further to control and regulate other noxious species as well.

⇒ *Plant Protection Ordinance (1924, amended 1956 and 1981, and wholly revised 1999)* - this ordinance restricts the introduction into Ceylon (now Sri Lanka) and spread therein of weeds, pests and diseases injurious to and destructive of plants and for the sanitation of plants. It was totally revised in 1999 (No. 35) to provide adequately for current trends on the movement of flora and fauna due to increased international trade and traffic.

⇒ *Fauna and Flora Protection Act of 1937,* and its amendments, provides for the establishment and maintenance of national reserves, national parks and jungle corridors for the preservation of biological diversity.

⇒ A revised *National Seed Policy* on the import of seed and planting materials to Sri Lanka was prepared by the Department of Agriculture in 1991, and a new *Seed Act of 1999* is pending formal approval.

These documents provide considerable legal support to act against the introduction of IAS. However, their interests and scopes are limited and they do not have the overall requirement to act against IAS. The Plant Protection Ordinance of Sri Lanka aims at preventing introduction of alien pests (insects, diseases and weeds) which are harmful to agricultural, horticultural and forest-based industries. However, quarantine laws give less emphasis to plant species that can have serious negative effects on biodiversity of natural habitats of Sri Lanka. Thus, it is clear that development of an appropriate legislative framework is a pre-requisite for effective prevention and subsequent control of IAS.

Table 3. Recently recorded agriculturally important alien pests

Pest species	Crop
Acaphylla theae	tea
Aleurodicus dispersus	fruit crops & ornamentals
Aceria guerreronis	coconut
Globodera rostochiensis	potato
Liriomyza sativae	vegetables
Liriomyza huidobrensis	vegetables
Meloidogyne graminicola	rice
Steneotarsonemus spinki	rice

Source: De Silva (2001); Wijesekara (2001)

National priorities in relation to IAS

The Ministry of Environment and Natural Resources of Sri Lanka has considered formulating a "National Action Plan for the Control of IAS" and a "National Experts' Committee on IAS" as top priorities to deal with the threats of the alien invasions. The draft of the IAS Action Plan has already been submitted for comment to this experts' committee and to a group of parliamentarians of the Sri Lankan Government for consideration. The Biodiversity Secretariat of the Ministry of Environment and Natural Resources has also placed great emphasis on awareness programmes to educate the general public on the adverse impacts of IAS. Research on biology, impact and control of IAS is also receiving attention.

IAS have important influences on numerous economic sectors, beyond the obvious impacts on agriculture and forestry. Managing invasions successfully requires a coordinated strategy, based on cooperation among all land managers (Marambe, 2001b). The management strategies will rely upon the scientific expertise of cooperating research agencies and institutions, to develop sound scientific information for managing invasive alien plants. To overcome further detrimental impacts on agricultural and natural ecosystems, the policy makers of Sri Lanka must put management of IAS high on the list of national resource management priorities.

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Annex 1. Summary list of activities to control AIS in Sri Lanka, with contact details

Salvinia molesta

The State Department of Agriculture is currently conducting a biological control programme for *Salvinia molesta* using the weevil *Cyrtobagus salviniae*. This has been considered as one of the most successful bio-control programmes in the country, especially in the low-country wet zone. The weed has been declared as a serious pest by the Plant Protection Ordinance.

Contact address: Deputy Director/Plant Protection Service,
Department of Agriculture, Peradeniya, Sri Lanka. Tel: +94-8-388316

Eichhornia crassipes

The State Department of Agriculture is rearing the bicontrol agent *Neochetina eichhorniae*, but the bicontrol seems to be far behind the expected success rate as the agent does not feed effectively on the invasive aquatic weed. Recently the Department of Agriculture, in collaboration with the Irrigation Department of Sri Lanka, also launched a chemical control programme for *E. crassipes* in irrigation canals in the northwestern province.

Contact address: As above under *Salvinia*

Parthenium hysterophorus

The State Department of Agriculture, together with Ministry of Environment and Natural Resources, universities and other governmental, non-governmental and private organizations is actively involved in programmes related to control of *Parthenium hysterophorus*. An extraordinary gazette notification was released by the government of Sri Lanka in December 2000, prohibiting the movement of materials contaminated with any part of *P. hysterophorus* from the infested areas.

Contact address: As above under *Salvinia*

Mimosa pigra

Many non-governmental organizations, in collaboration with the Ministry of Environment and Natural Resources, are actively involved in campaigns to create awareness among people and eradicate small patches of this IAS, especially from the central province. Recently, the Ministry of Irrigation also established a committee to eradicate *Mimosa pigra* and other aquatic weeds from the surrounding areas of the major rivers in Sri Lanka. Technical assistance is provided by the University of Peradeniya and State Department of Agriculture.

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E-mail: bmarambe@cropsci.pdn.ac.lk

President, Socio-Environmental Foundation of Central Province
Kaikawaela, Matale, Sri Lanka.Tel. +94-66-55277

Awareness programmes:

The Ministry of Environment and Natural Resources and IUCN Sri Lanka are currently conducting and sponsoring programmes to create awareness on the impact and control of alien IAS in Sri Lanka.

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CEA Building, Battaramulla, Sri Lanka, Tel. +94-1-887454, envgreen@sltnet.lk

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Annex 2. Address list of government and non-government organizations.

Ministry/department/NGO	Address
MINISTRIES	
Ministry of Environment and Natural Resources	Sampthpaya, Battaramulla, Sri Lanka
Ministry of Agriculture, Livestock and Samurdhi	Govijana Kendraya, Battaramulla, Sri Lanka
Ministry of Water Management	Colombo
Ministry of Tertiary Education	Ward Place, Colombo 7, Sri Lanka
DEPARTMENTS	
Department of Agriculture	Peradeniya, Sri Lanka
Biodiversity Secretariat	Ministry of Environment and Natural Resources, Sri Lanka
Central Environmental Authority	Ministry of Environment and Natural Resources, Sri Lanka
Environment Action 1 Project	Ministry of Environment and Natural Resources, Sri Lanka
Irrigation Department	Jawatta Road, Colombo 7, Sri Lanka
Upper Mahaweli Watershed Development Project	Polgolla, Sri Lanka
Mahaweli Authority	TB Jaya Mawathe, Colombo 10, Sri Lanka
Faculty of Agriculture	University of Peradeniya, Sri Lanka
Faculty of Science	University of Peradeniya, Sri Lanka
Faculty of Science	University of Colombo, Sri Lanka
Faculty of Agriculture	University of Ruhuna, Sri Lanka
Biodiversity Division	Customs Department, Sri Lanka
NON-GOVERNMENTAL ORGANIZATIONS	
World Conservation Union, IUCN	Horton Place, Colombo 7, Sri Lanka
Socio-Environmental Foundation	Kaikawela, Matale, Sri Lanka
Hantana Conservation Society	Peradeniya, Sri Lanka
Society of Environmental Education	Nugegoda, Sri Lanka
Young Zoologists' Association	Colombo, Sri Lanka

Annex 3. List of IAS experts in Sri Lanka.

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Mr. S. Gunasekera	Biodiversity Division, Customs Department, Colombo, Sri Lanka	
Prof. IAUN Gunatillake	Senior Professor, Department of Botany, Faculty of Science, University of Peradeniya, Sri Lanka	+94-8-388693
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Thailand

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Introduction

Thailand has no single or centralized national authority responsible for prevention and management of invasive alien species (IAS). This responsibility is divided among different ministries such as the Ministry of Agriculture & Cooperatives (MOAC) in the Department of Agriculture (DOA) for plants, insects, plant pathogens, and biological control agents; Department of Livestock Development (DOLD) for microorganisms and animals of livestock and veterinary importance; Department of Fisheries (DOF) for fish and aquatic animals and plants (freshwater and marine); Royal Forest Department (RFD) for other plants, shrubs, trees, wildlife and endangered animals listed under the Convention on International Trade in Endangered Species CITES; Ministry of Public Health (MOPH) in the Department of Medical Science (DOMS) and the Department of Communicable Disease Control (DOCDC) for microorganisms and causal agents of epidemiological importance; Ministry of Commerce (MOC) for the import and export of certain kinds of flora and fauna. While plant quarantine is under the Department of Agriculture, animal quarantine is under the Department of Livestock Development, both of which are under the Ministry of Agriculture & Cooperatives.

The issues of IAS have become more urgent in Thailand and are one of the major concerns of the country (although it will only ratify the CBD in 2004). Following the UN/Norway Conference on Alien Species in Norway (July 1996 ; see Waage this volume), the National Environmental Board Sub-committee on the Convention on Biological Diversity decided to establish a Working Group (WG) on Alien Species in January 1997. This was situated in the office of Environmental Policy and Planning (OEPP) - the official CBD national focal point, under the Ministry of Science, Technology and Environment (MOSTE), which also functioned as the secretariat of the WG. The OEPP also serves as the secretariat of the CBD Subcommittee, which is chaired by the permanent secretary of MOAC.

The WG on Alien Species is chaired by the executive director of the National Biological Control Research Centre (NBCRC) and co-chaired by the deputy secretary-General of OEPP. It is a joint venture between Kasetsart University and the National Research Council of Thailand (NRCT). Members of the WG consist of representatives of the secretaries' various ministries and boards. The Working Group on Alien Species had the following tasks :

- Compile information on the status of alien species in Thailand;
- Compile information and conduct investigations on the biology, ecology and impacts of alien species in Thailand;
- Prepare guidelines and measures for the control and eradication of those alien species affecting and causing economic damage;

- Prepare guidelines to regulate the introduction of alien species including genetically modified organisms (GMOs); and
- Undertake any task assigned by the CBD Subcommittee.

Inventories

Under the WG on Alien Species, Thailand has accomplished a considerable amount of work, such as preparing inventories of alien species which take into account both invasive and alien species that have proven to be more beneficial than harmful. Although the number of known alien species of microorganisms, plants and animals in Thailand is still far from being reasonably estimated, these inventories reflect, at the very least, the extent to which the alien species exist within the country. Some of the major inventories that have been undertaken thus far include:

- Endemic and alien microorganisms of livestock and veterinary importance prepared by the National Institute of Animal Health, DOLD, and MOAC. Based on culture collections maintained at the institute, researchers estimate that 19 of 168 virus/virus strains are alien, while 135 of 274 bacterial strains or serotypes, and one out of 31 protozoa are of foreign origin;

- The National Biological Control Research Centre (NBCRC) of Kasetsart University and the National Research Council of Thailand have identified 24 serious insect pests of agricultural importance as IAS. In addition, four vertebrate species have been introduced for biological control of water weeds, 12 insects for the biological control of terrestrial and aquatic weeds, two predatory snails for the control of the giant African snail *Achatina fulica*, and a total of 42 beneficial alien species for biological control of insect pests and weeds of agricultural importance as well as insect vectors of medical and public health importance. Thailand has also recorded two alien species for biological control of weeds from South America which have found their way through unknown means to Thailand and neighboring countries;

- The Department of Fisheries (DOF) has estimated that there are at least 32 species of introduced aquatic animals, including snails, in Thailand;

- Another authority has estimated that Thailand hosts 94 species of mammals, 168-228 species of birds, 63-93 reptile species, 23 species of amphibians, 218 fish species, four non-insect invertebrates, and 37 species of insects which were alien.

- The Royal Forestry Department (RFD) has reported 190 alien plant species, while the National Science and Technology Museum inventory documented 921 alien plant species, and the Office of Cane and Sugar Board under the Ministry of Industry estimates that there are 59 major alien weed species present in the sugarcane growing areas of the country. The Institute of Horticultural Research (DOA) maintains an inventory of horticultural crops imported into the country annually.

- The RFD documented that 116 bird species and 15 mammal species were brought into the country in 1995 under the Convention on the International Trade of Endangered Fauna and Flora (CITES). The Zoological Parks Organization of Thailand has identified 371 alien zoo animals in governmental as well as privately owned zoos.

Status of invasive alien species problems

Of the species included on the IUCN-Invasive Species Specialist Group's (ISSG[2]) list of 100 IAS, Thailand hosts at least one micro-organism, one aquatic plant, 13 land plants, nine land invertebrates (three snails, six insects), five fish, one bird and eight mammals. Several of these species were introduced to Thailand for specific purposes. Examples include: the rosy wolf snail *Euglandina rosea*, which is native to Florida (USA) and was introduced for biological control of the giant African snail *Achatina fulica*; fish species introduced as sources of protein, such as carp *Cyprinus carpio*, tilapia *Oreochromis mossambicus* and Nile perch *Latus niloticus*, and walking catfish *Clarius batrachus* and mosquito fish *Gambusia affinis* which were introduced for biological control of mosquito larvae.

Examples of invasive alien species

Invasive plants already identified in Thailand include: water hyacinth (*Eichhornia crassipes*), giant water fern (*Salvinia molesta*), giant sensitive plant (*Mimosa pigra*), Siam weed (*Chromolaena odorata*), mile-a-minute (*Mikania micrantha*), and croftonweed (*Ageratina adenophora*) among others. The latter two are invading the northern highland areas of Thailand, Myanmar, and Laos and appear to have come from India and China. Many of the problematic IAS in Thailand also cause high economic impacts in other neighboring Southeast Asian and South Asian countries as well.

Plants and other animals native to Thailand and other countries in Southeast Asia can become IAS elsewhere. For example, weeds of endemic origin in Southeast Asia, such as itch grass (*Rottboelia cochinchinensis*) and giant bramble (*Rubus alceifolius*), have also became IAS of economic importance outside of this region in South America, Reunion, and Mauritius, respectively. A semi-cultivated ivy gourd (*Coccinia grandis*) has traveled along with Southeast Asian refugees to Hawaii and became one of its worst weeds during the mid-1980s. Recently, an invasion of cycad scale (*Aulacaspis yasumatsui*) from Thailand was discovered in cycads shipped to Miami Botanic Gardens (Florida, USA) from Pattaya. The same scale insect was also discovered in California and Hawaii (USA) in early 2002. Immediate release of an insect parasite and a predatory nitudulid from Thailand into Miami has helped to lessen the problem.

List of existing programmes and other government agencies involved in IAS issues

The list of Thailand's existing programmes for IAS management, awareness raising, and national-level campaigns is very short. The only bold and clear-cut programme dealing with management of IAS was that of the National Biological Control Research Centre (NBCRC; established 1978) at Kasetsart University in collaboration with the National Research Council of Thailand (NRCT) and 17 collaborating universities and agencies under the MOAC, MOPH, and some other government enterprises. However, NBCRC deals only with biological control programmes aimed at IAS and within integrated pest management (IPM) systems operating through collaborations with other national, regional and international organization and institutions.

Other programmes relevant to IAS are expected to be identified and prioritised in accordance with Thailand's National Biodiversity Strategies and Action Plan (NBSAPs; 2002-2006) by the CBD subcommittee and the OEPP. When priorities for future work are identified, and policy recommendations, as well as necessary strategies management, are undertaken by the WG on Alien Species, the roles of other government agencies involved in biological control of IAS as well as in other IAS issues can be clarified. A bibliographic list of publications, references, journals, and other resources pertinent to biological invasions in Thailand is being compiled at present. The list of experts in the field of biological invasions and their corresponding contact information will be gathered in the near future.

[2] www.issg.org

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Overview

IAS have been present in Vietnam for a long time, and are known to cause harmful effects. The most well-established IAS are pests of agriculture. Some IAS have a very high invasive potential, and are listed on quarantine pest lists. The species that have caused the greatest damage in Vietnam are the golden apple snail (*Pomacea* sp.) to rice production and the mimosa plant (*Mimosa pigra*) to biodiversity conservation in national parks. Vietnam has practised integrated management of these IAS all over the country, as well as in specific regions to reduce crop losses and to maintain ecological balance. A case study of the golden apple snail in Vietnam is included. Strategies for future work in Vietnam are collecting information on IAS present in the country; enacting regulations on bio-safety including those for genetically modified organisms (GMOs) and their products; and strengthening measures for import and release of biological agents.

List of major alien species identified as IAS or pests

- *Pomacea* sp., golden apple snail (see case study below);
- *Tenebrio molitor* L., yellow mealworm beetle;
- *Ophiphagus hannah*, ho mang chua;
- *Myocaster coypus*, hai ly;
- *Mimosa pigra* L., mimosa plant.

The mimosa plant is not strictly speaking alien to Vietnam, but it has a restricted distribution in Vietnam and drifts from Cambodia along the flow of the Mekong River.

List of existing national IAS programmes (management efforts & awareness campaigns)

⇒ *Mimosa pigra* control

A project using a beetle (*Calosobruchus quadritatus*) as a biocontrol agent for *Mimosa pigra* was carried out at Nam Cat Tien National Park (in Dong Nai province) by the National Plant Protection Institute (NIPP). For more information on this programme please contact:

Dr. Nguyen Van Tuat, Director, National Plant Protection Institute
Ministry of Agriculture and Rural Development
Dong Ngac, Tu Liem, Hanoi, Vietnam

Tel: +84-8385578; Fax: +84-4-8363563
E-mail: nipp.vietnam@bdvn.vnmail.vnd.net or tuat@hn.vnn.vn

Another study of *Mimosa pigra* control, at Tram Chim National Park (Dong Thap province), has been carried out by Thu Duc University of Agriculture and Forestry and the Queensland Department of Primary Industry, Australia. The difficulty of this project is that seeds of the plant drift from Cambodia to Vietnam along the Mekong river annually. For more information on this programme please contact:

Dr. Bui Cach Tuyen - Rector
University of Agriculture and Forestry
Thu Duc, Ho Chi Minh City, Vietnam
Tel: +84-88960712 , 8960711
E-mail: ttgiang@hcm.vnn.vn

Evaluating project for culture of "hai ly" (coypu), *Myocaster coypus*, imported from China has been carried out by the Mushroom Thien Tan Ltd. Company in Hanoi. (Editors' note: untraceable project.) For more information on this programme please contact:

Mr. Le Hung Quoc - Director General
Department of Agricultural and Forestry Extension
Ministry of Agriculture and rural Development
No. 2 Ngoc Ha, Ba Dinh, Hanoi, Vietnam
Tel: +84-4 7332218 or 8234651
Fax: +84-4 8433811 or 8236403

List of organizations on the management of IAS in Vietnam

- ***Ministry of Science - Technology and Environment***
  National Environment Agency, Nature Conservation Division
  67 Nguyen Du, Hanoi, Vietnam
  Tel: +84-4 9424557; Fax: +84-4 8223189
  E-mail: baoton@hn.vnn.vn

- ***Ministry of Agriculture and Rural Development***
  Department of Science Technology and Quality Products
  No. 2 Ngoc Ha, Ba Dinh, Hanoi
  Tel: +84-4 8237737 or 8436814, Fax: +84-4 8433637

  Department of Plant Protection
  149 Ho Dac Di, Dong Da, Hanoi
  Tel: +84-4 8518198
  Fax: +84-4 8574719
  E-mail: ppdvn@fpt.vn

  Department of Animal Health
  Phuong Mai, Dong Da, Hanoi
  Tel: (84) 4 8685460 or 8693605
  Fax: (84) 4 8691311 or 8685961

Department of Agricultural and Forestry Extension
No. 2 Ngoc Ha, Ba Dinh, Hanoi, Vietnam
Tel: +84-4 7332218 or 8234651
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- ***Ministry of Fisheries***
  Fishery Resource and Environment Conservation Department
  10 Nguyen Cong Hoan, Thanh Xuan, Hanoi
  Tel: +84-4 7715082 or 8345953
  Fax: +84-4 8353363 or 8351759

- ***Other Institutions and Universities***
  Research Institute for Aquaculture No. 1
  Dr. Pham Anh Tuan
  Dinh Bang, Tien Son, Bac Ninh, Vietnam
  Tel: +84-4 8273072 or 8 271368
  Fax: +84-4 8273070

- ***Non-governmental organisations***
  IUCN-Vietnam
  13 Tran Hung Dao, Hanoi, Vietnam
  Tel: +84-4 9330012, Fax: +84-4 8258794

Priorities for future work and strategies

- Collecting information on IAS present in Vietnam and from other parts of the world;
- Enacting regulations on biosafety including those for GMOs and their products;
- Strengthening measures for import and release of biological agents.

List of experts in the field of biological invasions and their contacts

Please contact the above mentioned organisations for more details of experts, who are working in the field of biological invasions in Vietnam.

Case study on management of the golden apple snail

Introduction and spread of the golden apple snail

The golden apple snail (GAS), originally from the Amazon region of the South American continent, has spread to the other parts of the world such as Europe and Asia, and has seriously damaged rice production in many countries including Taiwan, Japan, The Philippines and Vietnam. This IAS was introduced to Vietnam in 1988 through many pathways due to absence of quarantine measures, but its source is unknown. At the beginning, GAS was considered as rich protein food for fish and duck, and therefore the Vietnamese were encouraged to culture GAS even in their home gardens. This resulted in GAS being brought from the South to the North, and distributed between various provinces of Vietnam for culturing.

In 1992, two farms for culture of GAS were established in Kien Giang province and Ho Chi Minh City by Vietnamese-Taiwanese joint venture companies. The main objective of the project was large-scale culture of GAS for export to Taiwan. However, the snail escaped from culture ponds and spread to the

outside, infesting other nearby ponds, trenches and rice fields. During seasonal flooding, this species spreads more rapidly in the Mekong delta region. Within 10 years of its introduction, it was found to occur in 57 of 61 provinces in the country. The data on GAS infestation in Vietnam collected in 1998 are as follows:

Year	Area of GAS infestation (ha)				Total (ha)
	Rice fields	Water spinach	Ponds, lakes	Trenches	
1994	1,678.1	140.3	-	-	1,818.4
1995	3,872.0	205.0	8,723.0	1,050.0	13,850.0
1996	57,863.0	2,087.0	12,923.0	2,744.0	75,617.0
1997	109,715.0	3,479.0	15,182.0	3,886.0	132,262.0

Source: Plant Protection Department 1998

The following types of losses are inflicted by this IAS to crops: reduction of seedling density and need for replanting seedlings 2-3 times per crop season, increased cost of pest control; reduction of farmer incomes; negative effects on tourism.

Management strategies

⇒ Policies, programmes and actions

Two decisions of the Prime Minister forbade culture, trade and movement of GAS within the country. A standing committee for controlling GAS at central and provincial levels was established, with representatives from agriculture, science-technology, environment and fishery agencies. Two national programmes for controlling GAS were carried out from September 1994 to June 1995 with the involvement of pupils, farmers, women, students and soldiers.

The most useful method for controlling GAS in Vietnam is hand picking. The figures for this method of control from some provinces are as follows.

Province	Collections of adults *(tons)*	Collection of eggs *(tons)*
Ho Chi Minh City	227.0	3.5
Nghe An	52.0	*26.6
Thua Thien - Hue	46.0	5.0
Tien Giang	41.0	3.5
Kien Giang	39.0	3.7

* included egg carriers

⇒ Technical advice

Chemical and biological control strategies have been adopted for control of the snail, including application of botanical insecticides:

- Truc dao (leaf): *Nerium oleander* L. at 30-40 kg/ha
- Xoan ta (seed): *Melia azedarach* L. at 20-30 kg/ha
- Thuoc ca (root): *Derris* spp. at 30-40 kg/ha

Synthetic chemicals used are: CaO (600-750 kg/ha); CuSO4 (6-7.5 kg/ha), Padan (1-2 kg/ha); and Metaldehyde 6% (7.5-10 kg/ha). Use of fish species such as *Mylopharyngodon* sp. in ponds or lakes, and *Mylopharyngodon* sp., *Cyprinus carpio*, *Clarias fucus* and *C. gariepinus* in rice fields, was also effective. Ducks can also be good control agents.

⇒ Training farmers on Integrated Pest Management (IPM) methods

Two thousand, six hundred eighty-four Farmer Field Schools (FFS) on integrated pest management in rice were carried out in the country with 182,372 farmers attending them. During these field schools, farmers were trained on identification of GAS from other snails, their biological and ecological characteristics and control methods in rice fields, ponds, lake and trenches. Data from FFS training in some of the provinces are as given below:

Province	**Number of FFS**	**Number of farmers trained**
Minh Hai	584	17,922
Quang Tri	363	31,745
Kien Giang	327	13,476
Quang Binh	120	18,699

Implementation of integrated snail management in rice in Vietnam

This was carried out under a Food and Agriculture Organisation funded project (TCP/6611) from 1997-1998. The main out puts of this project were:

- Training of farmers on IPM of GAS through the national IPM programme, funded by FAO;
- Using GIS methods for collecting information on snail infestations for taking management decisions;
- Study and transfer of knowledge and application techniques to farmers on using of fish for controlling GAS.

The golden apple snail is now a common pest in rice fields in South of Vietnam. Sometimes it can reach outbreak proportions in rice fields in some of the provinces. Therefore, the content of farmer training programmes on IPM in rice now includes control of GAS, among other pests. In particular, this programme has been expanded in the Mekong delta area in southern Vietnam. Provincial leaders are expected to encourage students and farmers to hand-pick these species as much as possible when they are first detected. More information on this IAS in Vietnam can be obtained from the Plant Protection Department of the Ministry of Agriculture and Rural Development of Vietnam, at the address given below:

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