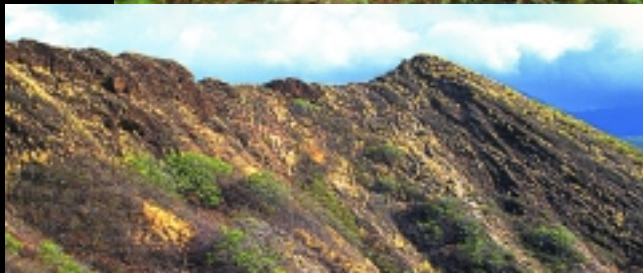
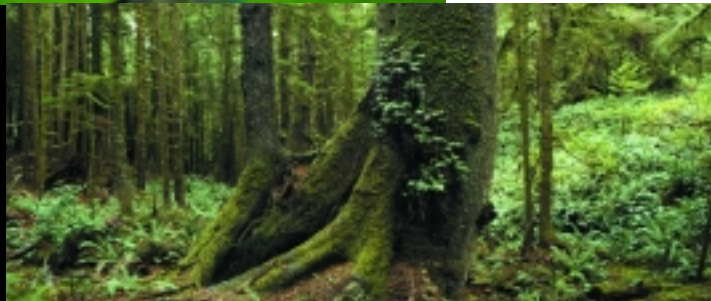


**ASSESSMENT AND MANAGEMENT  
OF ALIEN SPECIES THAT THREATEN  
ECOSYSTEMS, HABITATS  
AND SPECIES**



# **ASSESSMENT AND MANAGEMENT OF ALIEN SPECIES THAT THREATEN ECOSYSTEMS, HABITATS AND SPECIES**

*Abstracts of keynotes addresses and posters presented at the sixth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice, held from 12 to 16 March 2001 in Montreal, Canada.*

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## **FOREWORD**

The Convention on Biological Diversity (CBD), negotiated under the auspices of the United Nations Environment Programme (UNEP), was adopted in 1992 and entered into force in 1993. Its aims are the conservation of biological diversity, the sustainable use of biological resources, and the fair and equitable sharing of benefits arising from the use of genetic resources. One of the major challenges facing the Convention on Biological Diversity is the communication of research results in a way that provides the policy makers, their advisors, the scientific community and other stakeholders with helpful insights.

Major factors leading to biodiversity loss are habitat loss and degradation, invasive alien species, overuse of resources and pollution. Due to the complexity of these factors, various approaches and strategies are being used to reduce biodiversity loss. All, however, require the best available scientific information that allows the development and implementation of sound management strategies.

The goal of the CBD Technical Publications Series is to contribute to the dissemination of up-to-date and accurate information on selected topics that are important for the conservation of biological diversity, the sustainable use of its components and the equitable sharing of its benefits. A large and growing body of evidence has clearly established the need to disseminate synthesis publications relevant to CBD objectives and selected reports presented at CBD meetings.

The Technical Publications Series is intended to:

- Foster scientific and technical cooperation;
- Improve communication between the Convention and the scientific community;
- Increase awareness of current biodiversity-related problems and concerns; and
- Facilitate widespread and effective use of the growing body of scientific and technical information on conserving and using biological diversity.

The CBD Technical Publications Series comes at a time when the international community through the Conference of the Parties to the Convention has committed itself to achieving tangible results in all aspects of the sustainable management of biological diversity for social and economic purposes. We therefore believe that this series will be useful to the broader scientific community and those concerned with biodiversity management.

I am very pleased to make available to the scientific community and those actively involved in biodiversity management the first publication in the CBD Technical Series. It contains abstracts of posters and keynote addresses presented at the sixth meeting of the Subsidiary Body on Scientific, Technical and Technological Advice held in Montreal from 12 to 16 March 2001. The abstracts focus on one of the main factors leading to biodiversity loss, namely, invasive alien species, that threaten ecosystems, habitat and species. It is my hope that this publication will broaden our understanding of the complexity of the issue of invasive alien species and at the same time facilitate the implementation of remedial measures to reduce or halt biodiversity loss attributed to invasive alien species.

I wish to express my sincere gratitude to all those who have contributed in, one way or another in the preparation and production of this series.

***Hamdallah Zedan***  
*Executive Secretary*



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## **ABSTRACTS OF KEYNOTE ADDRESSES**

Invasive Alien Species—the Nature of the Problem  
*Harold Mooney*

Outputs of GISP Phase I and Future Plans of the Global Invasive Species Programme  
*Jeff Waage*



## INVASIVE ALIEN SPECIES—the Nature of the Problem

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Invasive alien species represent a major disruption for all biotic systems including terrestrial and aquatic, managed and wild. Invaders can have enormous economic and human health impacts as well as degrading many system properties that society values, including biodiversity. In order to illustrate these negative features of invasive species I briefly summarize our current general knowledge about their past and present status. I then focus specifically on how invasive species can devalue the ecosystem services upon which we all depend in all nations, developed and developing. This information forms the rationale for a new Global Invasive Species Strategy that will be discussed at this meeting.

### **What is an invasive alien species as commonly described?**

- A species that is new to a region
- Has a negative impact on the new environment, either, ecologically, economically or socially

### **What do we know in general about them?**

- There has been a massive mixing of biota globally driven by intercontinental commerce
- This mixing has been both purposeful and accidental
- Biotic enrichment as well as impoverishment has resulted from this mixing.
- A small fraction of aliens have become invasive but these few can do enormous damage
- Invasives represent all taxonomic groups and originate from all continents

### **What we know about the impacts of invasives?**

- Invasive alien species have altered evolutionary trajectories
- Invasives can disrupt community and ecosystem processes
- Invasives are causing large economic losses and are threats to human health and welfare and to sustainable development

### **Why we face a great challenge?**

- Invaders are self replicating
- Invasive microorganisms and insects, in particular, can quickly evolve responses to control efforts
- Lag times are common before adverse effects are seen
- Invaders alter and respond to community interactions in complex ways
- Movement of potential invasive material is increasing
- Global changes mostly favor invasives
- Information base inadequate for risk assessment
- Inadequate public awareness of the problem

# ABSTRACTS OF KEYNOTE ADDRESSES

## What we would like to know more about?

- The kinds and conditions of habitats where invasives are most successful
- The traits of successful invaders
- The vectors of invasives
- Mechanisms of habitat degradation due to invaders
- Cascading effects of invasives through ecological and socio-economic systems

## What we really want as scientists, managers or policy makers?

- A general (not likely) and reliable predictive model of invasive potential and of habitat invasibility
- Environmentally benign, and inexpensive methods for either the eradication or control of invasives
- The means to regulate the flow of potentially invasive organisms

I make the point that for most invasive alien species it is not difficult to demonstrate negative impact. I do this by illustrating the great number of ways in which an invasive alien species can threaten the goods and services provided by natural systems upon which society depends. This list includes species that are: Fire stimulators and cycle disruptors; Water depleters; Disease causers; Crop decimators; Forest destroyers; Fisheries disruptors; Impeders of navigation; Clogger of water works; Destroyer of homes and gardens; Grazing land destroyers; Species eliminators; Noise polluters and Modifiers of evolution.

I close with the words of Yvonne Baskin that capture the importance yet complexity of the invasive species issue, "The spread of invasive alien species is creating complex and far-reaching challenges that threaten both the natural biological riches of the earth and the well being of its citizens. While the problem is global, the nature and severity of the impacts on society, economic life, health, and natural heritage are distributed unevenly across nations and regions. Thus, some aspects of the problem require solutions tailored to the specific values, needs, and priorities of nations while others call for consolidated action by the larger world community."

# OUTPUTS OF GISP PHASE I AND FUTURE PLANS OF THE GLOBAL INVASIVE SPECIES PROGRAMME

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### ***The need for a global invasive species program***

Five years ago, only a handful of countries had an awareness of the invasive alien species problem that allowed them to address their responsibilities under Article 8h of the Convention on Biological Diversity. In 1996, a Norway/UN Conference on Alien Species brought representatives from over 80 countries together with technical experts on invasive alien species. From this meeting it emerged that:

- invasive alien species posed one of the greatest threats to global biodiversity loss
- most countries had insufficient awareness, information or capacity to address their invasive alien species problems
- access to existing expertise on invasive alien species was limited, and knowledge and solutions were not being effectively shared between countries

At this meeting, a concept for a Global Invasive Species Programme (GISP) was born. This was developed subsequently by three international organizations with specific and complementary expertise on invasive species issues, the Scientific Committee on Problems in the Environment (SCOPE), CAB International (CABI) and the World Conservation Union (IUCN). GISP was established with two objectives:

- to assemble and make available best practices for the prevention and management of invasive alien species
- to stimulate the development of new tools in science, policy, information and education for addressing these problems

GISP has been in operation since 1997 and has completed in 2000 its first phase of activity. It has been supported by voluntary contributions from its three coordinating institutions and from individual participants, and by grants from the Global Environment Facility and a range of private and public sector institutions. GISP works closely with UNEP and is a component of DIVERSITAS, an international programme on biodiversity science.

### ***GISP–Achievements of its first phase***

To achieve its two objectives, GISP assembled an international network of scientists, managers, policy specialists and lawyers, and established a three-year workplan centred on ten projects and the delivery of a specific set of practical outputs. Some GISP projects addressed the scientific basis for improving decision making, specifically our need to understand the current status of invasive alien species problems, their ecological and human dimensions and their significance in the context of global change. Another set of projects addressed the components of prevention and management of invasive alien species problems, including understanding the pathways of invasion, prospects for early warning systems and methods for rapid assessment. Related projects examined the need for improving legal and institutional frameworks, and the development of tools for economic assessment, risk analysis and education.

## ABSTRACTS OF KEYNOTE ADDRESSES

The specific outputs of this first phase of GISP are presented as a series of publications directed at particular stakeholder groups:

- For government agencies and civil society organizations, a Toolkit of Best Prevention and Management Practices, illustrated with 100 case studies from the developed and developing world, and a prototype Global Invasive Species Database which provides a format for a future global early warning system.
- For policy makers, a Global Strategy on Alien Invasive Species which explains the issues and identifies priority areas for work on invasive alien species, and a comprehensive Guide to Designing Legal and Institutional Frameworks on Alien Invasive Species.
- For the scientists and managers, a series of symposium volumes and studies addressing specific technical issues, including economic assessment, invasives and global change, pathways of invasions and human dimensions of the problem.
- For the general public a popular book on invasives drawn from the global experience and activities of GISP.

In September 2000, GISP organized a Synthesis Conference in Cape Town to finalize the outputs of its first phase, to begin the process of broadening participating in GISP and to design its activities in a new, second phase. Environmental and agricultural ministerial representatives from 42 developing and developed countries joined international experts on invasive alien species, representatives from 15 international organizations and conventions (including the CBD) and from 15 national and international non-governmental organizations. All contributed to the outputs of GISP's first phase and the planning of its future activities.

### *GISP's vision of the future*

GISP's vision of the future for invasive alien species issues is predicated upon the experience and knowledge which it has gained over the past three years. Many lessons have been learned, from which broad conclusions for action can be drawn. Some emerging conclusions include, for instance:

- the prevention of alien species is preferable to their control, because it is usually much more affordable.
- while prevention must involve improved measures for intercepting invasive alien species, most rapid progress may involve identifying and addressing key pathways invasive alien species introduction
- many problems are shared, and therefore can be solved by communicating and sharing successes between countries
- successful management may require substantial initial costs (e.g. for eradication or biological control), but these should be viewed as the incremental costs of implementing sustainable solutions in the longer term.

These are just a few conclusions emerging from GISP and presented in the publications of its first phase.

## ABSTRACTS OF KEYNOTE ADDRESSES

GISP has prepared a Global Strategy for policy and decision makers which explains the invasive alien species and lessons learned to date. It then identifies key areas for future work which will deliver the greatest practical benefit to governments and other stakeholders in meeting the invasive alien species challenge and the implementation of Article 8(h). These ten priority areas are:

- Building national capacity to manage invasive alien species problems
- Building capacity to undertake critical scientific, social and economic research
- Promote the sharing of information on invasive alien species and their management
- Development of economic policies and practical and effective economic tools
- Strengthening national, regional and inter-regional legal and institutional frameworks
- Development and extension of risk analysis to all invasive species problems
- Building public awareness and engagement
- Preparation of national invasive alien species strategies and plans
- Building invasive species issues into global change initiatives
- Promoting international cooperation to deal with invasive alien species problems

From this Global Strategy, GISP has selected itself five specific actions for its second phase, on the basis of their importance and the specific capacity of GISP to make a substantial, unique and cost-effective contribution.

Firstly, GISP proposes to help establish and operate a Global Clearing House for knowledge on invasive alien species, involving the further development of databases and the active dissemination of information. It will explore an additional potential role as a Centre for Invasive Alien Species, assisting with diagnosis, evaluation and rapid response for prevention and control.

Secondly, GISP will take directed action at key pathways of invasive alien species introduction, examining gaps in coverage of international mechanisms and informing government trade representatives to WTO on invasive species issues. It will focus particularly on private-public sector cooperation in developing voluntary codes of conduct and other regulatory systems associated with key pathways.

Thirdly, GISP will build on its substantial record of scientific research and publications to support development of research and research capacity in key “gap” areas, including taxonomy, risk analysis, new control methods, socioeconomic assessment. Particular emphasis will be placed on bringing together researchers from environmental, agricultural and other relevant sectors to share knowledge and undertake multidisciplinary research.

Fourthly, GISP will help countries to improve national capacity to prevent and manage invasive alien species and to develop regional, capacity-sharing initiatives. Over the next year, GISP will be coordinating a programme of regional workshops on invasive species supported by the US Environmental Diplomacy Fund in Europe, Asia, Africa and tropical America. These workshops will help the development of national and regional capacity. The GISP Toolkit for Best Prevention and Management Practices will be a valuable resource for national capacity building and training programmes, and the Global Invasives Database will be important to regional cooperation. GISP will make a specific effort to help national/regional pilot projects which combine a capacity building element with demonstrating widely the potential for success.

Finally, GISP will support co-operation between international organizations and initiatives by providing assistance to the coordination and development of guidelines and the harmonization of terminology.



## ABSTRACTS OF KEYNOTE ADDRESSES

GISP has been productive under its initial stewardship by SCOPE, IUCN and CABI. In a new phase, it will need to extend participation and ownership to a broader constituency, including governments, civil society organizations and other international initiatives. This process has already been started with the GISP Synthesis Conference in Cape Town, where governments, NGOs, international organizations and conventions and industry contributed to its forward planning.

### *The Contribution of GISP to the CBD*

GISP is a pro-active and inter-disciplinary initiative which assists the CBD and the implementation of Article 8h. Its independence and informality has been important to its success in bridging traditional institutional barriers between environment and agriculture, in linking invasives issues beyond conservation to global change, economics, industry, trade and international development, and to sharing the benefits of existing knowledge between rich and poor countries. In this way, GISP is helping the CBD to realize its objectives and to place these in a broader context.

GISP has made specific contributions to the CBD process and has potential to do much more in future. Experts identified by GISP have helped the Executive Secretary in drafting of the Interim Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species. In line with recommendations of the Conference of Parties (COP 5), GISP has also assisted in preparation of several information documents for SBSTTA 6 (in addition to its own publications, which will be distributed at SBSTTA 6). GISP has also contributed to a CBD Liaison Group on invasive species problems, held during its Synthesis Conference in September 2000.

GISP's Phase II Plan addresses specific decisions of COP 5 and proposed recommendations of SBSTTA 6. To undertake its future work, GISP will therefore seek the support and endorsement of SBSTTA, and appreciates Decision V/8 of COP 5 and its invitation to the Global Environment Facility, Parties, Governments and funding organizations to provide adequate and timely support to enable GISP to fulfil the tasks outlined in its Decision.

## ABSTRACTS OF POSTER PRESENTATIONS

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**EMERGING ISSUES: NONNATIVE ANIMALS IN WESTERN AQUATIC SYSTEMS**

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***Keywords: Trout; montane ponds; impact; management; nonnative fish; bullfrog***

Invasive species and changes in hydrology are two of the greatest threats to freshwater habitats in western North America (Richter et al. 1997). The two are interrelated and have been linked to major population declines of native aquatic organisms. Invasive aquatic plants have received much attention but exotic animals remain inadequately studied. The introduction of trout into permanent, naturally fishless montane ponds and lakes has been wide spread throughout the west (Bahls 1992). USGS Forest and Rangeland Ecosystem Science Center scientists have recently shown that large-bodied zooplankton (calanoid copepods) and amphibian larvae, the top native vertebrate predators, were greatly reduced in stocked waters compared to fishless systems (Liss et al. 1998). Moreover, experimental fish removal caused increases in salamander density in near shore habitats. These effects may fundamentally alter the dynamics of montane lakes throughout the west. Spatial and social issues complicate management of this problem. Further research is needed on the effectiveness of fish removal and on balancing conservation of aquatic biota with sport fisheries management at the landscape scale.

Unfortunately, the role of nonnative animals in low elevation systems is even more complicated. Wetlands in the lowland west were historically dominated by seasonal inundation regimes. The loss of many of these seasonal wetlands, combined with the shift from temporary towards more permanent hydroperiods has promoted the spread of a variety of nonnative fish and bullfrogs, and currently very few unaffected permanent habitats remain. FRESC scientists have found evidence that the detrimental effects on native wetland biota may vary regionally and that complex interactions among invasive species and physical habitat change can obscure interpretation of observed patterns (Adams 1999). In some cases, the physical changes that promote the spread of introduced animals may themselves be detrimental to native animals (Adams 2000). These complex interactions are in urgent need of further study.

We have only begun to address invasion resistance, mechanisms of invasion, and the interaction of landscape change with invasion. A recent experiment suggests that nonnative fish are facilitating the survival of nonnative bullfrogs (Fig. 1). A lack of funding for research on aquatic invasive animals has hampered progress. Regionally, nonnative animals have become the number one threat to our aquatic fauna, and information concerning invasive animals is critical for U.S. Department of the Interior resource managers. We urge greater support for research on nonnative fish, bullfrogs, crayfish, and other invasive animals in western aquatic habitats.

---

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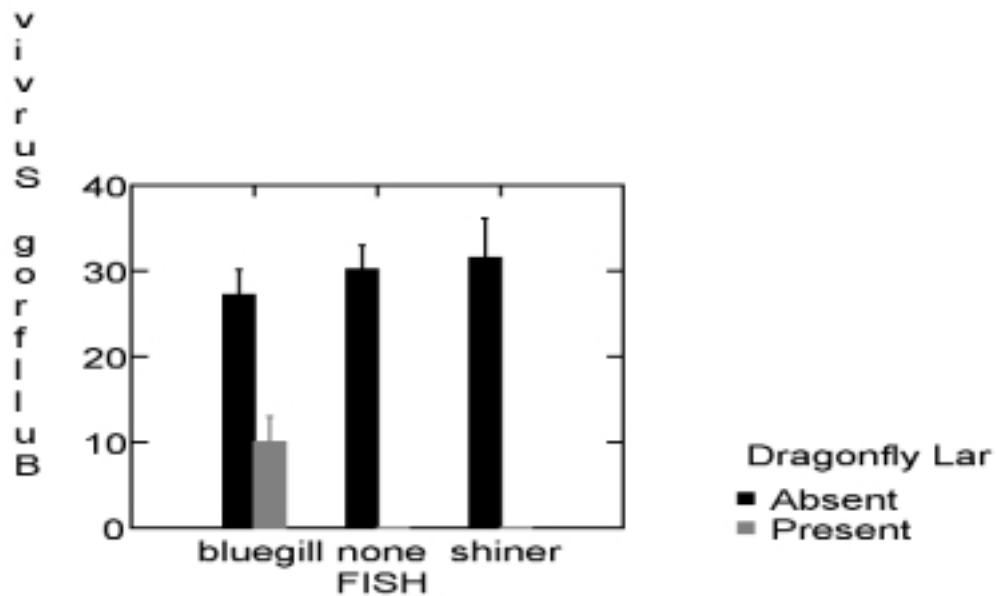
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**Figure 1.** In a USGS/EPA experiment, we found that nonnative bullfrogs could not survive in the absence of nonnative fish. Without nonnative fish, native dragonfly larvae ate all of the bullfrog tadpoles. Nonnative fish eat the dragonfly larvae.

## MUTE SWAN MANAGEMENT IN THE CHESAPEAKE BAY: A CASE STUDY

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***Keywords: aquatic vegetation, impact, waterbird, Cygnus olor***

The mute swan (*Cygnus olor*) is a European species that has been repeatedly introduced to the United States as an aesthetic addition to parks, zoos, and private lands. A feral population of mute swans has been expanding in the Chesapeake Bay since 1962, when five swans escaped captivity and established a breeding population. This population now exceeds 4,000 year-round resident birds, which are negatively impacting submerged aquatic vegetation and the nesting of other waterbirds, including species of concern such as black skimmers and least terns. Despite these ecological concerns, mute swans, like many exotic species, have a constituency that values them aesthetically and seeks to prevent harm to the swans. In light of the rising population and conflicts, the Maryland Department of Natural Resources convened a panel to review management options. This panel, consisting of wildlife professionals, concerned citizens and swan advocates, met five times over a two-year period to discuss values, problems, and visions of success. The eventual compromise solution will remove mute swans from areas of ecological concern, such as nesting colonies and critical aquatic vegetation beds, and will allow mute swan populations in more developed areas where humans can enjoy them, but where they pose little ecological threat. This process potentially provides a model for managing other exotic species that cause ecological damage but have proponent groups advocating their perpetuation.



## RECENTLY SPREADING ALIEN SPECIES IN GERMANY: SOUTH AFRICAN RAGWORT (*Senecio inaequidens*) AND AMERICAN MINK (*Mustela vison*)

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***Keywords: rapidly spreading species, Senecio inaequidens,  
Mustela vison, Germany, Central Europe***

### ***Introduction***

The alien plant species South African Ragwort (*Senecio inaequidens* DC.) has spread very rapidly in Germany since the 1970s. It prefers ruderal sites along transport routes (railways, highways), and on urban wasteland, slag heaps, construction sites and other anthropogenically disturbed locations, where the plant becomes dominant particularly in late summer. The extraordinary rapidity of its spread as well as the possible increase in its competitive capacity in various plant communities justify taking a closer look at *S. inaequidens*.

Several wild populations of the alien animal species American Mink (*Mustela vison*) exist in Germany. *M. vison* lives semi-aquatically on rivers, forest brooks, lakes, and in reeds and swamp forests. The exact distribution of the species, the size of its populations and their impact upon the local ecosystems are largely unknown. The American mink is suspected of displacing the European (Old World) Mink, *Mustela lutreola*. In addition, it has been observed that the rapidly spreading populations have serious impacts on their prey species.

### ***Description of the alien species and their impact on threatened ecosystems***

#### ***South African Ragwort (*Senecio inaequidens*)***

##### ***Biology and Ecology***

*Senecio inaequidens* is a perennial shrubby herb about 60 cm high. It is poisonous to humans. Its flowering period lasts from May to December and has continuously shifted "forward" during recent years. In its native region, *S. inaequidens* DC. originally colonizes skeletal sectors on steep, moist and grassy slopes, as well as the sandy and gravelly banks of periodic streams at elevations between 1400 and 2850 m. In Germany *S. inaequidens* grows on warm and dry ruderal sites, mostly with gravelly or sandy soil. The species is found on railroad locations, on the dividing strip of highways, at river ports, on flat roofs and in flower tubs, logging areas and storm-damaged forests, at industrial sites, and in abandoned quarries.

##### ***Vectors of invasion***

*Senecio inaequidens* was introduced via wool imports. In the early 1970s *S. inaequidens* was propagated with the westerly winds - being anemochorous - from the region of Liège (Belgium) to western Germany. The species is now spreading eastward along linear anthropogenic structures, in particular along railway lines and highways. Frequent maintenance measures (e.g. creation of open soil surfaces by "stripping" on the dividing median of highways) represent an important vector. It has been observed that the species is exceptionally resistant to herbicides, and it is apparently promoted by mowing as well. It may be assumed, that control measures provide a competitive advantage. The plant's ability to reproduce increases considerably with a gradual warming of the climate.



### *Actual impacts on threatened ecosystems*

*Senecio inaequidens* does not demonstrably pose a threat to autochthonous species or plant communities at present. In central Europe the plant rather appears to fill vacant ecological niches. It equally grows at locations that had been largely devoid of vegetation, for instance on the gravel of railroad tracks and on slag heaps impacted by heavy metals. It needs to be considered, however, that *S. inaequidens* is a perennial herb with a woody stem base, forming stands capable of exerting strong competitive pressure (e.g. by shading) on small annual and biennial ruderal species. *S. inaequidens* depends on the anthropogenic disturbance regime, and remains incapable of permanent establishment in an undisturbed process of succession. Up to now it remains unclear whether the colonization of near-natural spaces (such as rocky sites on the central Rhine) may put indigenous species at risk. Lately it has been observed that *S. inaequidens* does form dominant populations on areas of broken rock. A threat to autochthonous species of great importance to nature conservation (e.g. blue lettuce, *Lactuca perennis*) may therefore not be excluded.

### *American Mink (Mustela vison)*

#### *Biology and Ecology*

The mink is nocturnal and lives semi-aquatically on brook and river banks with dense vegetation, in (alder) forest marshes, reed beds in sedimentation areas of lakes, and marshes furrowed by channels. It mostly hunts small mammals, ground-nesting birds, and amphibians. During the winter, the mink mostly feed on juvenile fish and therefore prefer to stay in the proximity of open water bodies including fish ponds. Mink have also been repeatedly sighted near fowl farms. Preliminary observations in the Müritzer National Park show that the preferred prey of the local mink population are an aquatic fowl, the coot (*Fulica atra*) and a crustacean species, the crayfish (*Cambarus affinis*).

#### *Vectors of invasion*

*Mustela vison* was introduced for breeding in European fur farms in the late 1920s. Until recently, the animals were raised in great numbers for their valuable fur. About 500,000 furs were produced annually in East Germany (the former GDR) in the mid-1970s. Individual animals repeatedly escaped into the wild, but initially remained unable to establish permanent populations. 1966 "liberations" by animal protection activists caused major escapes. The mink spreads very rapidly throughout regions with many lakes and watercourses and an abundance of fish, such as the Mecklenburg-Brandenburg lake district and the pond cultures of the Upper Palatinate. Especially fish ponds are "stepping stones" of dispersal. The emergence of reed belts and willow and alder shrubbery on abandoned agriculture in wetlands also leads to an expansion of mink habitats.

### *Actual impacts on threatened ecosystems*

The mink is an aggressive predator on certain animal taxa. An analysis of the stomach contents of seven mink from the area of the Löcknitz, a tributary of the River Spree in the Berlin region, showed that about three-fourths of the food items consist of amphibians, small mammals, mollusks and fishes. The predation pressure on populations of amphibians, in particular those of edible frogs and marsh frogs (*Rana esculenta*, *R. ridibunda*), is extraordinarily high, because their preferred habitat coincides with the mink's principal hunting territory. The prey spectrum of 16 animals from the Upper Palatinate region mostly consisted of fish, birds and small mammals. The mink is also suspected of displacing its close relatives, the European mink, *Mustela lutreola* (which is threatened by extinction), and the European polecat, *Mustela putorius*.

### *Conclusions*

A monitoring program is advisable in those parts of the range of *Senecio inaequidens* in Germany where the species shows massive colonization pressure on locations outside its preferred the ruderal (e.g. xerothermic locations on rocks), or is capable of doing so (cereal cultures). A monitoring program should focus particularly on expulsion mechanisms between *S. inaequidens* and thermophilous native species with poor competitive capacity, as well as potential impacts on agriculture (resulting from this poisonous species' invasion of food products).

A nationwide monitoring program for American Mink is urgently recommended. It should focus on the mechanisms by which mink displace native species, as well as the potential damage to fish farming. Information on the distribution and spreading of *Mustela vison*, and on its ecosystem impacts is urgently needed.

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## RISK ASSESSMENT FOR MANAGING THE TROPICAL WEED, MIMOSA PIGRA

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***Keywords: Mimosa pigra, risk assessment, training, tropical weed***

### ***Introduction***

The pressure on many tropical wetlands is increasing as human populations and development activities increase. As a consequence, many wetlands have been lost and degraded. In recent years the extent of degradation caused by invasive species has been recognised and many management actions taken, often addressing the effect rather than the cause(s). This is the case for the thorny shrub *Mimosa pigra* (known colloquially as mimosa) that has now become a major pest in many tropical wetlands (Rea & Storrs 1999).

Within this context we have collated an information base on the biology and management of mimosa as a case study for the application of a risk assessment procedure designed to assist weed managers. Much of the information for this assessment has come from northern Australia, where mimosa has been seen as a major weed for more than two decades, and from South East Asia where it is increasingly becoming a major menace.

### ***Wetland Risk Assessment Framework***

A wetland risk assessment framework has been encouraged under a formal resolution of the Ramsar Wetlands Convention (van Dam et al. 1999). The framework contains six steps, as shown in Figure 1.

1. Identification of the problem – identify the nature of the problem and develop a plan for the remainder of the assessment, including the objectives and scope.
2. Identification of adverse effects – evaluate the likely extent of adverse change.
3. Identification of the extent of the problem – estimate the likely extent of the problem.
4. Identification of the risk – integrate the results from the above steps.
5. Risk management and reduction – make decisions to minimize the risks without compromising other societal, community or environmental values.
6. Monitoring – verify the effectiveness of the risk management decisions.

### ***Mimosa pigra wetland risk assessment***

#### ***Identification of the problem***

*Mimosa* is native to tropical America where it occurs in a wide belt extending from Mexico through Central America to northern Argentina. It has been introduced to other areas and is now widespread and a serious weed. It can spread rapidly and invade large areas of tropical wetlands. The extent and consequences of such invasions were assessed on the basis of existing information and recommendations made for control measures, including training, and information gaps identified.

### *Identification of adverse effects*

Mimosa is an enormous problem in Australia with floodplains and swamp forest being invaded by dense monospecific stands of mimosa, which have little understorey except for mimosa seedlings and suckers. For native species, the impact is severe and many animals have become scarce or have disappeared. However, some species have increased in the short term or along the outer edges of the infestation! The extent of such changes is not well known.

Mimosa also interferes with the lifestyles of indigenous peoples who rely on the natural environment. It can disrupt stock watering, irrigation, tourism, and recreational use of waterways. In Thailand it has resulted in sedimentation in irrigation systems and reservoirs. In many cases economic impacts are contingent with ecological impacts. For example, tourism is affected directly by restricted access to floodplains and by loss of income in a range of associated service activities. Another economic impact is the financial cost of controlling the weed. In northern Australia it is estimated that more than US\$12 million has been spent on research and control of mimosa.

### *Identification of the extent of the problem*

Mimosa favours a wet-dry tropical climate and has been introduced into most tropical regions of the world where it can grow in dense thickets in comparatively open, moist sites such as floodplains, coastal plains and riverbanks. In its native range it occupies similar habitats, especially in areas which have been disturbed, but usually occurs as small thickets or as individual plants. In 1975 only a few mimosa plants were known to occur in wetlands in northern Australia; by 1989 it reportedly covered 80 000 ha and could extend to 4,200,000 ha, although these figures have not been corroborated and in many locations information on the extent of the problem does not exist.

### *Identification of the risk*

The risk of infestation for many wetland habitats in tropical countries is high and the cost of management high. Mimosa has many features that are generally considered 'advantageous' to a weed. The rapidity with which it can spread and develop impenetrable thickets is well known, as is the difficulty of control. Given these features the risk of infestations spreading and resulting in severe problems is high.

### *Risk management and reduction*

In northern Australia the recommended strategy for controlling mimosa is to prevent initial invasion, eradicate small infestations by physical or chemical means and, for large infestations adopt an integrated approach involving biological control, herbicide application, mechanical removal, fire and pasture management. All of the above require some level of training and logistical support. Interruptions in control programs wastes time, resources and funds, and allows mimosa time to recover from past treatment. Common problems with controlling mimosa are a lack of awareness of the problems that could occur if the weed is not effectively controlled, and discontinuity in control.

### *Monitoring*

Monitoring to prevent the introduction and establishment of mimosa is essential. Areas likely to be infested can be regularly surveyed and machinery etc that is likely to carry propagules can be inspected and cleaned. Critically, monitoring should be ongoing and directed towards priority sites or processes, and where necessary training provided so that this is done effectively.

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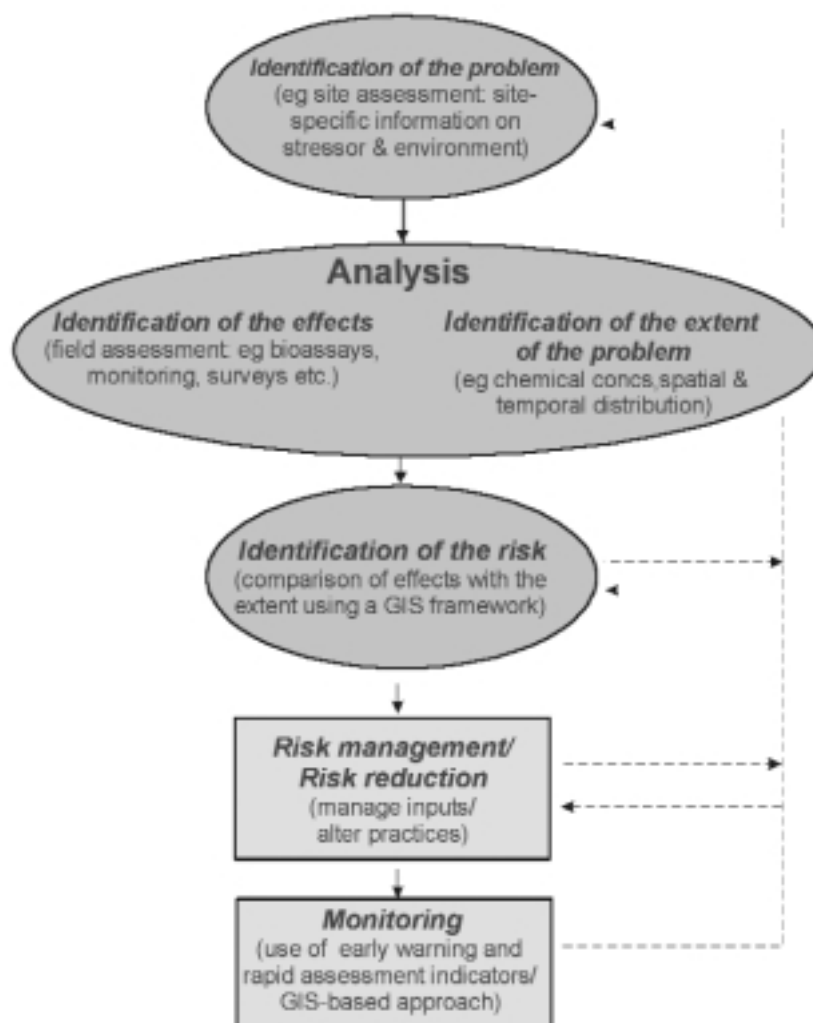
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**Figure 1. Model for wetland risk assessment (updated from van Dam et al. 1999)**





## ECOLOGICAL RISK ASSESSMENT OF THE CANE TOAD, BUFO MARINUS, IN KAKADU NATIONAL PARK, AUSTRALIA

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**Keywords:** *Cane toad, Bufo marinus, risk assessment, monitoring, risk management*

### **Introduction**

The cane toad, *Bufo marinus*, was introduced to Australia in 1935, and has since expanded its range to occupy most of tropical north-eastern Australia. This wet season (2000-2001) will see the arrival of cane toads in Kakadu National Park (KNP), a World Heritage area with Ramsar-listed wetlands. In preparing for their arrival, a preliminary risk assessment was undertaken to predict key habitats and species most likely to be at risk, from which recommendations for new monitoring programs could be made, the relevance of existing programs evaluated, and some management options identified.

### **Methods**

The approach, based on a wetland risk assessment framework developed for the Ramsar Convention on Wetlands (van Dam et al. 1999), involved identification of: the problem; the (potential) effects; the (potential) extent of the problem; the subsequent risks; and the information gaps (Figure 1). The outcomes were used to provide advice for monitoring and risk management. Major information gaps relevant to predicting impacts and developing appropriate monitoring programs were also identified.

The risk assessment was based on information from published and unpublished, scientific and anecdotal reports. A number of relevant governmental agencies were consulted, as were cane toad, native fauna and/or wildlife management experts from around Australia. Discussions were also held with indigenous communities in regions where cane toads already existed, to overview the potential indigenous/cultural impacts of cane toads.

### **Cane Toad Risk Assessment Identification of the problem**

Cane toads eat a wide variety of prey, have greater fecundity and develop faster than native anurans, and possess highly toxic chemical predator defences. They tolerate a broad range of environmental and climatic conditions, and can occupy many different habitats. To date, no effective control methods for cane toads have been developed. There is concern that the status of KNP could be diminished if any of the Park's natural and cultural values are negatively affected by cane toads.

### **Key habitats**

Cane toads will occupy almost all the habitats within KNP, although the saline regions and open water habitats were identified as being of less concern. Habitat preference will vary with season, with floodplains and sheltered habitats on the margins of floodplains and shallow billabongs providing ideal cane toad habitat during the early to mid dry season, permanent water being sought during the late dry season, and the drier but sufficiently moist woodlands and open forests being preferred during the wet season. Breeding activity will be concentrated during the wet season, but could also occur during the dry season, particularly after rain.



### *Species at risk*

A total of 154 predator species or species groups were listed as potentially at risk from cane toads, although varying degrees of risk and priority were assigned depending on the quality and quantity of available information. Ten species were assigned to risk category one (ie high risk) based on information of population declines due to cane toads. Of these, the northern quoll (*Dasyurus hallucatus*) was assigned highest priority due to its diminishing range, while the nine remaining species, including five varanid lizards, three snakes, and the dingo were assigned high priority. Another group of species was identified as being of high priority based on recorded deaths of individuals, and information on habitat, feeding ecology, behaviour and status. These included other small carnivorous mammals, the remaining six species of varanid lizard, pythons, ghost bat, black-necked stork, freshwater crocodile, and a range of native frogs. Some species, including the majority of fish, and a number of birds and mammals were assigned a low priority status based on relevant ecological, feeding, habitat or behavioural information. However, the risks to the remaining predator species identified are essentially unknown due to a lack of information.

Risks to prey species were difficult to predict, but those most likely to be impacted included termites, beetles and ants. Similarly, risks to potential competitor species were unclear, but potential effects to some native frog species and insectivorous lizards were of concern.

### *Cultural impacts*

The major impacts on Aboriginal communities within KNP will be a decline in some traditional foods, and in some situations, the alteration of ceremonies following declines of food and totem species.

### *Uncertainty and information gaps*

A great deal of uncertainty surrounded the prediction of risks. Contributing to this was a lack of understanding or quantitative data on I) both short and long term impacts of cane toads on animal populations; II) populations, distributions and general ecological information on Kakadu fauna; and III) potential cane toad densities within Kakadu.

### *Recommendations*

Historical or current monitoring programs within KNP need to be supplemented with additional data to provide a suitable baseline for the assessment of toad impacts. Priority species for monitoring included northern quoll, the varanid lizards, several elapid snakes and dingo. Other species warranting close attention included some small mammals, black-necked stork, freshwater crocodile, and a range of native frogs.

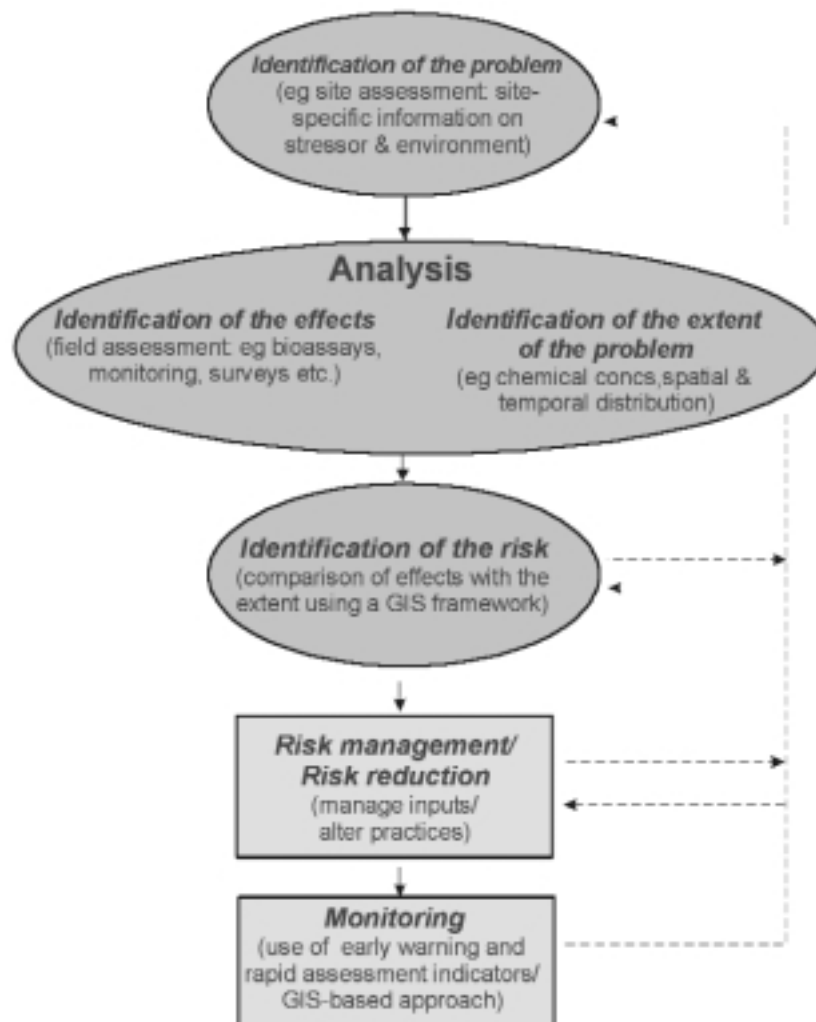
It was suggested that particular, sustained control measures may prove effective in localised areas (eg camping grounds), but as alternative control methods are insufficiently developed at present, broad scale control is not possible. Thus, it was recommended that KNP management respond to the imminent invasion of cane toads initially by I) ensuring that monitoring efforts are underway to assess impacts of cane toads to KNP, II) investigating measures by which cane toads can be managed on a localised basis, and III) conducting cane toad awareness programs for Rangers and local communities.

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Figure 1. Model for wetland risk assessment (updated from van Dam et al. 1999)





## NONINDIGENOUS AQUATIC SPECIES WEBSITE

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### ***Keywords: database***

The U.S. Geological Survey's (USGS) Nonindigenous Aquatic Species (NAS) Program maintains a nationwide database of introduced aquatic organisms, both freshwater and marine. It is a locational database that documents the distribution of introduced species and spatially references all locations to drainages (using USGS hydrological units). Access to portions of the database is provided via the Internet at <http://nas.er.usgs.gov>.

The NAS web site contains information on recent reports, meetings, group-specific information, links to other sites on nonindigenous species (organized by group, habitat, and region). Much of the species-specific information is accessed by choosing a taxonomic group of interest (mammals, reptiles, amphibians, fish, tunicates, bryozoans, sponges, annelids, coelenterates, sponges, crustaceans, mollusks, algae, or plants). From here a user can obtain information on distribution (including maps), access species-specific fact sheets, perform spatial queries, or access charts and graphs of summary information. The web site provides access to an extensive body of data. As of August 1, 2000, the database contains more than 24,500 records of introduced animals and approximately 20,000 records of introduced plants.

One of the most frequently used sections of the database are the queries. From the NAS web site a user can get a listing of species introduced into a state or into a particular drainage. This information is valuable to resource managers in determining potential threats to native species in the area they manage.

The background data contained in the database but not currently portrayed on the web site includes specific information on location, drainage, habitat parameters, date of introduction or collection, status of the introduced population (established, collected, extirpated), and the original source for the information (a publication or personal communication). The sources of data include published scientific literature, museum and herbarium specimens, field studies, state and federal agencies, universities, and private citizens. We hope to make more of this data accessible in the near future.



## NONINDIGENOUS FISHES INTRODUCED INTO INLAND WATERS OF THE UNITED STATES

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### ***Keywords: book on fish introduction***

This book, recently published by the American Fisheries Society, is based on more than 20 years of research and on an extensive and on-going electronic database of over 500 nonindigenous fish species in the United States. The book summarizes the historical trends and spatial patterns of fish introductions nationwide and gives an overview of the database itself, which is a major subset of a larger research database of other nonindigenous aquatic species.

In the introduction, the book attempts to answer some of the following questions about introduced fishes:

- 1) Where do they come from?
- 2) Is this a growing problem?
- 3) How do they get introduced?
- 4) Where are they introduced?
- 5) What states have the most species introduced?
- 6) Which drainages have the most introduced species?

Armed with such information, we can find ways to reduce or prevent future introductions by targeting areas with large numbers of introductions or intercepting known pathways.

The main focus of the book, the species accounts, provide details on taxonomy, identification, size, native range, nonindigenous occurrences, methods of introduction, population status, known impacts of the introduction, and voucher specimens for the more unique records or species. A distribution map is provided for each species depicting both the native and introduced range at a state by state basis; this information is also presented a comprehensive species/state matrix at the end of the book.

The book provides an extensive reference list (more than 50 pages) and is a valuable resource for anyone desiring to better understand fish zoogeography in the United States.



## MANAGING INVASIVE ALIEN SPECIES IN NATURAL HABITATS: THE ROLE OF BIOLOGICAL CONTROL

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***Keywords: Invasive alien species; natural habitats; biological control***

### ***Introduction***

One of the major factors that affects resource management schemes, such as land use, watershed and conservation programmes, is invasive species: aggressive aliens outside their natural range (as distinct from introductions such as crops which bring economic benefits). At the UN – Norway Conference on Alien Species (1996), invasive aliens were recognized as the second largest threat to biological diversity after habitat destruction on continents, and the greatest cause of biodiversity loss on islands. Problems caused by invasive aliens in agricultural systems are well known, but it is only relatively recently that the extent of damage caused to natural ecosystems has been recognized, e.g. by invading weeds such as water hyacinth (*Eichhornia crassipes*) in tropical water systems.

Article 8(h) of the Convention on Biological Diversity (CBD) states that contracting parties to the Convention should, as far as possible and appropriate, prevent the introduction of, control or eradicate those alien species that threaten ecosystems, habitats or species. Biological invasions in natural habitats frequently cover large areas and/or are difficult to target because of their inaccessibility. Management practices have to be environmentally benign, so they do not disrupt other parts of the invaded ecosystem. Biological control, by the introduction of host specific natural enemies, has often proved an effective and environmentally sound approach to alien invasive pest management. It is particularly well suited for invasive species in natural habitats because, once agents are released and established, they are naturally self-sustaining.

### ***Case Studies***

#### ***Water hyacinth, a global threat to inland water systems***

Water hyacinth, which is native to South America, was introduced into tropical and sub-tropical countries as an ornamental in the late 1800s. It has since spread throughout inland waterway systems worldwide, affecting the livelihoods of local communities, blocking rivers, lakes and canals, and dramatically altering the function of the invaded ecosystems. It can be controlled with herbicides but this has been expensive and can be damaging to non-target species.

Surveys for potential biological control agents in the native range of the plant were begun in the mid-1960s and led by CABI Bioscience (then the Commonwealth Institute of Biological Control). Several plant feeding insects were discovered from the water hyacinth; in particular, two weevil species (*Neochetina eichhorniae* and *N. bruchi*) were identified and have been shown to be highly host specific to the target plant. These two species have been released, singly or in combination, on water hyacinth in all the major continents affected by the plant and have provided outstanding control in many, but not all, affected areas (Julien and Griffiths, 1998). In some situations, other host specific agents were used with the weevils to improve the level of control. New work is examining the possibility of using additional agents, particularly fungal pathogens, to target water hyacinth areas where effective control has yet to be achieved.



### *Introduction*

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Surveys, funded by the US Department of Agriculture (USDA) are being conducted in the Upper Amazon region of northern South America to determine the potential of specialized (coevolved) fungal pathogens as classical or introduced biocontrol agents of water hyacinth worldwide. Whilst in Africa, a Danish (DANIDA)- funded project is currently in progress with the aim of developing a natural pesticide (mycoherbicide) based on an indigenous fungus.

*Orthezia insignis, a threat to endemic gumwood trees in St Helena*

The gumwood tree (*Commidendrum robustum*) is an example of the astonishing endemic flora of the island of St Helena in the South Atlantic Ocean. These trees once formed much of the woodlands that cover all the higher areas of the island. In the 1970s/80s an alien plant sucking insect, *Orthezia insignis*, was accidentally introduced into the island. It spread to the gumwood, and outbreaks rapidly killed large patches of the trees. Laboratory host range tests suggest that other endemic tree species on the island are also at risk of extinction from this pest.

*Orthezia insignis* is highly polyphagous and widespread throughout the tropical world, but is native to South America. This invasive species has been successfully controlled in several other countries through the introduction of a specialized predatory coccinellid beetle, *Hyperaspis pantherina*, which also originates from South America. Given the difficult terrain where the gumwood trees grow in St Helena, together with the risks of non-target effects of insecticides, biological control, though the introduction of *H. pantherina*, was considered to be the most practical and cost-effective strategy for management of the invasive alien insect. The work was funded by the UK Department for International Development (DFID, then the Overseas Development Agency). The coccinellid was released in 1993-94 and soon brought the insect pest under control. Local communities helped with the artificial dispersal of *H. pantherina*, which greatly enhanced the impact of the project (Booth et al., 1995).

**Conclusion**

CABI Bioscience has been working with other countries on biological solutions to invasive species problems in natural habitats, and similar successes have been achieved or are close; e.g. control of purple loosestrife in North America and rubber vine in Australia. Biological control, through the introduction of natural enemies, provides a long term sustainable solution that requires no further inputs once it has been implemented. International standards and methods are now available to ensure the safety of planned introductions of biological control agents (see IPPC, 1996). CABI Bioscience and other international organizations can provide advice on these to interested countries and programmes.

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## ALTERATION OF FRESHWATER ECOSYSTEMS BY THE INVASIVE BIVALVES, ZEBRA MUSSELS (*DREISSENA POLYMORPHA*) AND QUAGGA MUSSELS (*DREISSENA BUGENSIS*)

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***Keywords: spread, damage, Dreissena, prevention, Limnoperna***

*Dreissena*, one of most successful invasive species in North America, alter aquatic ecosystems by redirecting energy flows from pelagic to benthic food webs. Since 1986, these mussels have spread throughout the Great Lakes, down the Mississippi River, and into many inland waterways. At high population densities, up to 750,000/m<sup>2</sup>, positive and negative, abiotic and biotic changes occur. Initial concerns regarding damage to human underwater infrastructures proved short-lived, with measures for infrastructure protection, and redesign rapidly implemented. Ecosystem problems remain unchecked because species-specific control methods are not yet available. Most ecosystem impacts relate to *Dreissena*'s filter-feeding capacity. These animals utilize a variety of foods ranging from 0.2-250 microns. At large mussel densities, much of the suspended organic material in the water column is removed. Biota relying on planktonic foods, including the Unionidae, are extirpated. Biota that do not rely on planktonic resources thrive on the increased substrate and food provided by dreissenid colonies. However, decreasing suspended organic matter affects portions of every trophic level and every water user, including changes such increases in aquatic vegetation, increases in blue-green algae, and in inland waters, increases in the use of aquatic herbicides. The disruption in the Great Lakes' ecosystems due to recent fluctuations in *Dreissena* populations makes these waters particularly vulnerable to new invasions. Other invasive species, such as *Limnoperna fortunei*, are poised to enter North American waters. Prevention is more effective than control.



## WATERSHED CHARACTERISTICS AND NONINDIGENOUS FISH IN MID-ATLANTIC (USA) STREAMS

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***Keywords: Nonindigenous fish, exotics, invasive species, small order streams,  
Mid-Atlantic region, watershed characteristics***

The establishment of nonindigenous species in freshwater systems in the United States seems to be rising sharply. An existing US EPA data set, collected from 1993 - 1995 for Mid-Atlantic small order streams, was analyzed using multiple regression to learn more about the role that watershed condition plays in invasion biology and whether watershed characteristics can be used as a predictive tool. Sixty percent of Mid-Atlantic streams contain nonindigenous fish species and, on average, there were about seven times more native fish species in the sampled streams than nonindigenous fish. The number of nonindigenous fish species is related positively to the number of native fish species and both natives and non-natives are positively correlated to the size of the watershed. The more disturbed the watershed, the more exotic species occurring in the sampled stream. Distance to the ocean, population density and the number of point source dischargers did not correlate with the number of nonindigenous species. Native species are impacted by point source dischargers; the more dischargers, the fewer natives. The number of nonindigenous species increased in the sampled streams and, by extrapolation, the entire Mid-Atlantic region. This study is the first to document for the Mid-Atlantic region a statistically significant increase in nonindigenous species within just a three-year period. Although the ability to predict invasiveness is elusive, this study does offer some potential for using watershed characteristics to predict the invasion of small order streams by nonindigenous fish species.



## THE VALUE OF AWARENESS AND EARLY INTERVENTION IN THE MANAGEMENT OF ALIEN INVASIVE SPECIES: A CASE STUDY ON THE ERADICATION OF MIMOSA PIGRA AT TRAM CHIM NATIONAL PARK AND U MINH THUONG NATURE RESERVE, VIETNAM

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**Keywords:** *Mimosa pigra eradication, Tram Chim, U Minh Thuong*

### **Introduction**

The introduced Central American prickly shrub *Mimosa pigra* (*Mimosa*) is one of the most serious environmental weeds on freshwater wetlands of Viet Nam. The invasion of this weed is particularly aggressive in protected wetlands where ecosystem management is often ineffective due to shortages of funding and expertise. This paper reports lessons learnt from the on-going eradication of *Mimosa* at Tram Chim National Park and U Minh Thuong Nature Reserve, Viet Nam. At U Minh Thuong, the invasion of *Mimosa* was detected early, and the eradication was completed with little cost, using manual removal methods. At Tram Chim, however, the infestation of *Mimosa* has gone beyond easy management. It is also becoming an agricultural pest in the surrounding region. An experiment was conducted at Tram Chim to determine suitable eradication methods. A more forceful intervention program is recommended for Tram Chim, employing the short-term use of appropriate chemicals coupled with on-going manual removal. Finally, a long-term weed management strategy is outlined to assist staffs of both Tram Chim and U Minh Thuong in managing environmental weeds.

### **Methods**

The eradication of *Mimosa* at U Minh Thuong was done using manual techniques. Before cutting *Mimosa* stems, all seeds were collected and burned. After cutting the stems, all *Mimosa* roots were removed from soil. Cut stems and roots were then removed from the sites and burned. At Tram Chim, the map of areas infested by *Mimosa* was created from field measurements. To determine a suitable control method for Tram Chim, a randomised-block-designed experiment was conducted to test the effectiveness of four treatments: stem-cutting, fire, combination of stem-cutting and fire, and combination of stem-cutting and flood. Each treatment was randomly applied to ten 100m<sup>2</sup> experimental units which were placed in 10 blocks of four experimental units each. In each experimental unit, experimental parameters were measured in ten 1m<sup>2</sup> quadrats systematically placed within the unit. A weed management strategy was prepared based on the principles of wetland risk management (van Dam et al. 1999; [www.ramsar.org](http://www.ramsar.org)).



## *Results and discussions*

### *U Minh Thuong*

The core zone of U Minh Thuong Nature Reserve (16,000 ha, centred at 9°35'44"N, 105°05'30"E) is a peat swamp forest dominated by *Melaleuca cajuputi* (Myrtaceae). Being aware of the problem of *Mimosa* invasion in the Mekong Delta through training, staff of U Minh Thuong detected the presence of *Mimosa* in the Reserve at an early stage of infestation. Manual eradication was performed in May 2000, completely removed all living *Mimosa* plants. A weed control unit was established, patrolling the Reserve once a month since to search and eradicate newly established *Mimosa* plants, as well as to watch for other concerned environmental weeds such as *Urochloa mutica* and *Panicum repens*. The Reserve is still challenged by the abundance of many aquatic weeds, of which the most outstanding are *Eichhornia crassipes*, *Pistia stratiotes* and *Salvinia cucullata*.

### *Tram Chim*

Tram Chim National Park (7,600 ha, 10°37'-10°46'N, 105°28'-105°36'E) preserves a mosaic of swamp forests, seasonally inundated grasslands and permanent water bodies, located in the freshwater zone of the Mekong Delta. As recorded by the Park's staff, the first *Mimosa* plants were seen at Tram Chim around 1985. By 1999, the infested area was estimated at about 150 ha. The distribution map of *Mimosa* at Tram Chim, completed in June 2000 under this study, showed an infested area of 490 ha. The map also indicated areas highly susceptible to *Mimosa* invasion - some 4,600 ha, or 60% of the Park's land surface. The invasion of *Mimosa* at Tram Chim exceeds the capacity of the Park's staff to get the weed under control.

Results of the *Mimosa* control experiment showed that stem cutting, fire and combination of stem cutting and fire were not effective in eradicating *Mimosa* at Tram Chim. Living *Mimosa* plants were difficult to burn, and cut stems resprouted quickly after treatment (Table 1). It was also observed that fire might trigger germination of *Mimosa* seeds. Cutting *Mimosa* stems during the flood season proved to be the best method amongst those trialed. Tram Chim wetlands are subjected to 4 to 6 months of flooding every year. In the experiment, *Mimosa* stems were cut when flood water was about 30 cm above soil surface. Four months after the treatment, when flood water was still 60 to 80 cm above soil surface, no treated plants had resprouted, and 75% to 90% of roots of treated plants were dead.

A more forceful eradication programme is recommended for Tram Chim entailing training in chemical control and occupational health and safety, a program of chemical intervention for a limited time, and finally a long-term manual control program which forms part of a holistic strategic weed management program (Storrs 2000). The purpose of the programme is to quickly reduce the *Mimosa* infestation to a level manageable by Tram Chim's staff. A long-term weed management strategy is recommended for Tram Chim (and also for U Minh Thuong) for the future, including the following components: (i) prevention, (ii) early detection and intervention through the use of early warning and rapid assessment indicators, (iii) reduction of infested areas through the application of suitable control methods and continuous efforts, and (iv) monitoring and adjustment of practices.

### *Lessons learned*

*Mimosa* was detected and recognised as a potential problem in U Minh Thuong and appropriate actions were taken before the infestation was very large. Even though *Mimosa* invasion was noticed early at Tram Chim, due to lack of awareness, no weed control practice was applied until the eradication became complicated and costly. This case study demonstrates that awareness and early intervention can make the eradication of alien invasive species effective, yet inexpensive. Awareness and early intervention are even more meaningful in developing countries where there is a lack of funding for the management of alien invasive species.

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**Table 1. Means (and standard errors in parentheses) of measured experimental parameters of the *Mimosa pigra* control experiment undertaken at Tram Chim National Park.**

	Stem cutting	Fire	Cut and Fire	Cut and Flood
SD-0 (stems/m <sup>2</sup> )	2.0 (1.51)	2.31 (1.45)	2.41 (1.78)	1.65 (1.01)
SD-a (stems/m <sup>2</sup> )	0 (0)	0.57 (0.91)	0 (0)	0 (0)
SD-1 (stems/m <sup>2</sup> )	1.39 (1.56)	1.22 (1.00)	1.13 (1.15)	0 (0)
SD-2 (stems/m <sup>2</sup> )	1.20 (1.27)	1.20 (1.05)	1.13 (1.15)	0 (0)
SD-4 (stems/m <sup>2</sup> )	(not measured)	(not measured)	(not measured)	0 (0)
NS-1 (shoots/m <sup>2</sup> )	3.75 (4.51)	2.84 (4.16)	4.42 (5.33)	0 (0)
H.NS-1 (cm)	34.57 (30.36)	27.62 (31.29)	32.75 (26.51)	0 (0)
NS-2 (shoots/m <sup>2</sup> )	2.78 (3.64)	2.18 (2.83)	2.97 (3.79)	0 (0)
H.NS-2 (cm)	63.70 (60.09)	59.70 (57.21)	65.78 (56.63)	0 (0)
NS-4 (shoots/m <sup>2</sup> )	(not measured)	(not measured)	(not measured)	0 (0)
H.NS-4 (cm)	(not measured)	(not measured)	(not measured)	0 (0)
DB-0 (g/m <sup>2</sup> )	679.4 (610.5)	(not measured)	(not measured)	328.1 (360.8)
DB-2 (g/m <sup>2</sup> )	61.4 (86.7)	(not measured)	(not measured)	0 (0)
DB-4 (g/m <sup>2</sup> )	(not measured)	(not measured)	(not measured)	0 (0)

Abbreviations for parameters are SD-0: stem density before treatment, SD-a: stem density right after treatment, SD-1: stem density one month after treatment, SD-2: stem density two months after treatment, SD-4: stem density four months after treatment, NS-1: number of new shoots one month after treatment, NS-2: number of new shoots two months after treatment, NS-4: number of new shoots four months after treatment, H.NS-1: height of new shoots one month after treatment, H.NS-2: height of new shoots two months after treatment, H.NS-4: height of new shoots four months after treatment, DB-0: dry (above ground) biomass before treatment, DB-2: dry (above ground) biomass two months after treatment, DB-4: dry (above ground) biomass four months after treatment.



## A STRATEGY FOR GALAPAGOS WEEDS

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**Keywords:** *Alien plants, prevention, eradication, mitigation, strategic approaches*

### ***The Problem***

Galapagos is an isolated oceanic archipelago of volcanic islands lying 1000 km west of Ecuador, straddling the equator. Human settlement commenced after 1535. The rapidly increasing settled population has been accompanied by an enormous number of new introductions of alien plants and animals (Mauchamp 1997). 96.4% of the land area of Galapagos forms the Galapagos National Park. Inhabited areas (urban and agricultural zones, military bases and airports) make up the rest. The settled areas are the major source of invasion into the Galapagos National Park.

The Galapagos islands support a native vascular flora of about 500 species, with an additional 60 doubtfully native species. By January 2001, more than 600 introduced vascular plant species had been registered in the archipelago (Database of the Galapagos Flora, Charles Darwin Research Station).

The principal threat to the terrestrial biota of Galapagos is introduced species (Loope et al. 1988). Most (c. 75%) of the alien plant species (and a higher proportion of the worst invaders) were introduced deliberately as useful plants (see Mauchamp 1997). Some 45% of introduced plant species have naturalized (A. Tye unpublished data). 37 species have been identified as a significant threat to ecosystems, mostly trees, thicket forming shrubs, vines and grasses.

### ***The Strategy***

The strategy for dealing with these problems comprises five levels of action: prevention, control and eradication, restoration, the research required to prioritize and develop appropriate techniques to carry out these actions, and development of a legal framework for their effective implementation.

### ***Risk Assessment and Prioritization***

An essential first step is prioritizing the problems, given limited resources for control. Permitted lists for import of species and products have already been drafted, based on a preliminary risk assessment procedure, while all introduced plant species have been subject to a subjective risk assessment. A formal risk assessment system is currently being developed. Risk assessment and prioritisation will also be applied to sites. This is already done in a subjective manner, but a more formal site prioritisation system based on conservation value is being developed.

### *Research*

The successful use of a risk assessment system depends on the availability of sound scientific data on the distribution, biology and ecology of the introduced species.

Research on control techniques is also essential, including by monitoring control work.

Restoration research is only just beginning in Galapagos. The initial focus is on methods of control combined with positive restoration action.

### *Prevention*

Prevention is the first stage of management action. A quarantine system for Galapagos has been designed and its implementation commenced (Zapata et al. 2000). An early-warning and rapid response strategy is being planned for species that evade these controls. The system deals equally with transport between the islands.

### *Eradication and Control*

The new alien plant strategy for Galapagos formalises the prioritisation of eradication. Eradication is considered for two groups of plants:

- plants that are known to be invasive in other parts of the world but are present in Galapagos in very small populations and are not regarded as indispensable by the local community, and
- plants that are seriously invasive already in Galapagos, but for which an assessment indicates that eradication might be feasible.

Control is undertaken where eradication is not currently considered feasible but where the plant is considered to pose a significant conservation risk.

For valued species the control strategy would have to include replacement by a non-invasive substitute.

### *Restoration*

Monitoring of selected control sites will provide data that will be used to identify needs for positive intervention to restore native vegetation communities and to design such projects. It is expected that, in appropriate cases, this will lead to active restoration management following intensive plant control.

### *Legal framework*

A comprehensive "Special Law for Galapagos Province" was passed by the Ecuadorian Government in 1998. Regulations for the implementation of the new law are currently being drawn up, including sections on quarantine and introduced species management. Weed risk assessment will be written into these regulations, as will requirements for planning for the control and eradication of introduced plants. The regulations will place legal obligations on various public and private bodies, as well as on individual landowners, to undertake specified actions in regard to declared weed species or new introduced plants, including monitoring, reporting, controlling and eradicating. Such regulations and obligations are especially essential for the success of eradication efforts, where all populations of the species, whether on public or private land, must be treated.

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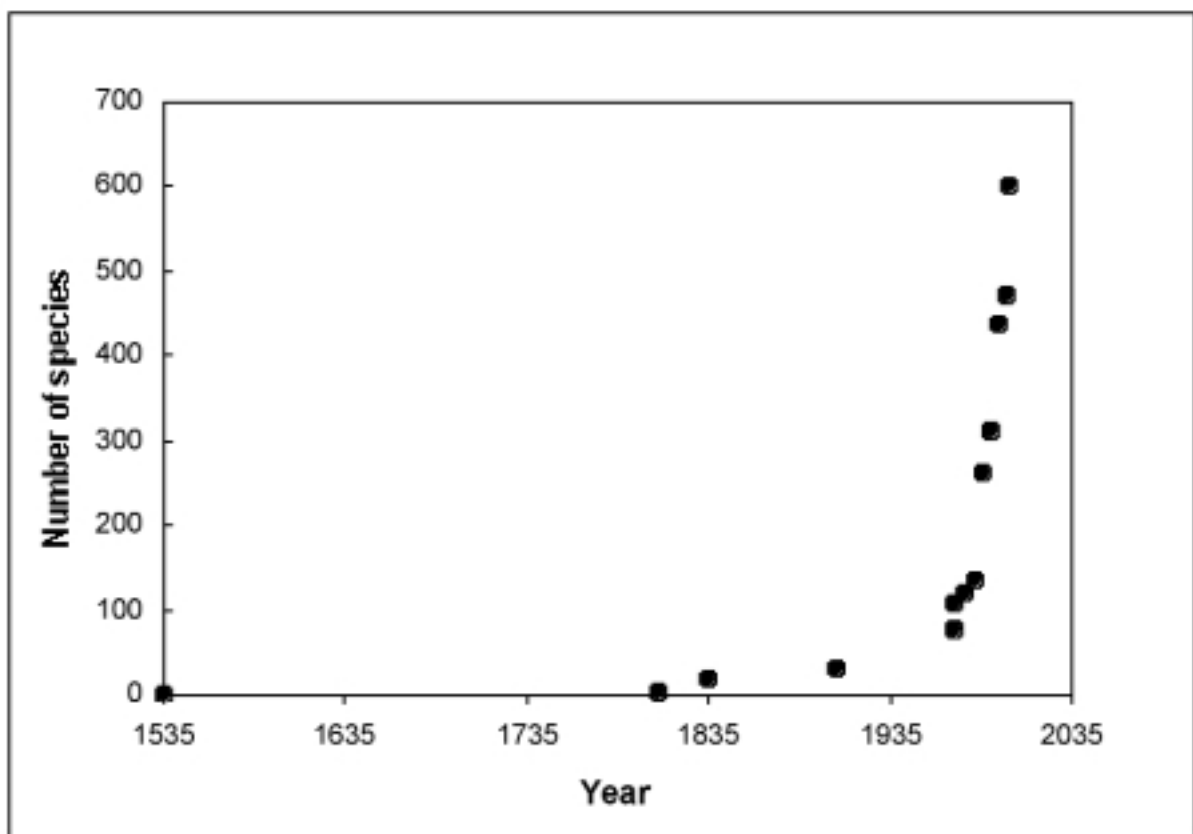
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**Fig. 1** Rate of increase in numbers of introduced plant species recorded in Galapagos since their discovery in 1535 (Tye in press).



### *Resumen*

Galápagos cuenta con una flora vascular nativa de algunas 500 especies, más 60 especies que son dudosamente nativas y más que 600 especies introducidas adicionales. Los organismos introducidos constituyen el problema más grave que enfrenta la biota nativa. Las peores plantas invasoras son árboles y otras especies leñosas, trepadoras y pastos, y la mayoría de las especies que están causando o podrían causar problemas fueron introducidas a propósito. Muchas de estas especies han invadido el Parque Nacional Galápagos, y son igualmente agresivas en las zonas agrícolas. Una estrategia para enfrentar este problema incluye prevención, control, erradicación y restauración, las investigaciones necesarias para desarrollar y priorizar estas acciones de manejo, y el desarrollar de un marco legal para su implementación. El primer paso es desarrollar medidas para priorizar los problemas, tomando en cuenta los recursos limitados para el control. Un sistema de evaluación de riesgos se está desarrollando, para evaluar tanto especies que ya se dan en las islas y para introducciones propuestas. Este último forma parte de la prevención: un sistema de cuarentena para Galápagos ha sido diseñado, y su implementación iniciado. La cuarentena puede reducir pero jamás parar las introducciones, pero es necesario para cambiar el equilibrio entre la introducción y la erradicación. El control y erradicación tienen dos componentes: investigación y manejo. Las investigaciones de la ecología y distribución de las plantas introducidas nos permiten determinar los factores necesarios para diseñar programas de control y erradicación que sean exitosos, tales como tasas de reproducción y dispersión, longevidad de plantas y semillas etc. La investigación para desarrollar nuevos métodos de control también se necesita, por lo que muchas especies invasivas en Galápagos son especies útiles y no han sido sujetos del control en otras partes. La investigación para la restauración ya empieza, con su enfoque en combinar acciones de restauración positivas en combinación con el control., tales como siembra de especies nativas. El programa de plantas introducidas en Galápagos está creciendo rápidamente, por lo que las plantas invasoras han sido solo recién ampliamente reconocidas como de alta prioridad. Los primeros proyectos para investigar la ecología de las malezas más graves ya son produciendo resultados. Los ensayos de control llevan al desarrollo y uso de métodos de campo eficientes. Se han iniciado intentos para erradicar especies aun representadas únicamente por pequeñas poblaciones, pero las cuales están conocidas como invasoras graves en otros lugares. También ha comenzado un proyecto piloto para evaluar la factibilidad de erradicar un árbol invasora bien establecido. Estas medidas, aparte de su valor científico y para la conservación, además pueden aumentar la confianza y cambiar la opinión general sobre el peligro de las especies introducidas y la factibilidad de su control.

## CLIMATE-MATCHING CAN BE USED TO PREDICT EXOTIC SPECIES INVASIONS

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### ***Introduction***

The economic and ecological costs associated with non-indigenous species invasions are staggering (US Congress 1993). A large share of this high price goes toward controlling species that have already become established - in hopes of curtailing the amount of damage they cause. Preventing invasion or establishment of noxious species is more cost effective than post-establishment control. Ideally, land managers would have a "hot list" of species to watch for and eradicate should they appear. I test the hypothesis that similarity in climate between the invaded (host) region and the native region of plant species can be used to predict the magnitude of risk that the host region would be subject to by plant species from various places around the world. This type of climatic-matching is not meant to produce the ideal mentioned above, but to serve as a first, coarse sieve to narrow the scope of future investigations. By identifying areas that harbor the most climatically pre-adapted species, scientific efforts can be focused to determine which of those species pose serious threats as invaders.

### ***Methods***

I used data from the Global Ecosystems Database (GED) (NOAA-EPA Global Ecosystems Database Project 1992). In selecting which variables to include in my model I drew heavily on the framework of BIOCLIM (Busby 1986, 1991) - a model that successfully predicts the distributions of plant species in Australia. I calculated 16 climatic variables for south Florida and all of Australia. For each of the variables included in the model I calculated the absolute value of the difference between the south Florida mean value and the value for each half-degree block in Australia. Thus, the lower the resulting number, the more similar the two areas are in a particular aspect of climate.

I compiled a list of all native and non-indigenous plant species that have been recorded in the natural areas of south Florida. I compared this list with a comprehensive census of Australian vascular plants (Hnatiuk 1990) and identified those species which were either: 1) native to Australia and nonindigenous in south Florida; 2) native to south Florida and nonindigenous in Australia; 3) native to both south Florida and Australia; and, 4) nonindigenous in both south Florida and Australia. I then accessed the Species Mapper Database from the Environment Australia<sup>8</sup> internet server (<http://www.environment.gov.au/search/mapper.html>) and downloaded location data for the species that belonged in any of the four categories above.



### *Results and Discussion*

South Florida and Australia share 236 species of vascular plants representing 69 families. More species (72) were nonindigenous in both south Florida and Australia than in any other category, however, nearly as many (71) were native to south Florida and occur as nonindigenous in Australia. By contrast, only 44 species were native to Australia and nonindigenous in south Florida. Forty-nine species were native to both areas. I performed a multiple discriminant analysis using location data for all 73 species represented in the Species Mapper database and all 16 climatic variables.

The primary purpose of this research is to identify areas where species are climatically pre-adapted to become non-indigenous components of the south Florida flora. As both discriminant functions outlined above satisfactorily identify such areas - one by using all species shared by Australia and south Florida, the other using only those species that are native to Australia and non-indigenous in south Florida - I applied each to the entire data set and plotted the results as maps (Fig. 1). I performed the same analyses for the Americas and Africa.

### *Application of Results*

The results of my analyses will be used to focus research on areas that have the greatest potential for contributing species to the already severely invaded natural areas of south Florida. The results also suggest a mechanism to control the introduction of nonindigenous species to any host area of interest.

In considering the literally countless terrestrial species spread over the 15 billion ha of land on the earth one easily succumbs to despair in attempting to predict what will comprise the next wave of non-native species. By using host-area specific climatic-matching I have limited the search area to a few well-defined, albeit large, regions. The next step is to look at these select regions at a higher resolution. Within regions with predicted high numbers of climatically pre-adapted species are there habitat types that correspond with those present in the host area? Do species within similar climatic regions persist in similar habitats? Are they invasive? These and other questions can be addressed with climate as a controlled variable. By first delineating a search area using host-area specific climatic matching, then cataloguing which species are there and in which habitat types they persist, one can begin to develop the ideal "hot list" of species that natural area managers can use to prevent future non-native invasions. Furthermore, the relationship between host-area climate and potential for non-native invasions could be investigated separately for terrestrial and aquatic plants, the latter having more relaxed habitat compatibility compared to the former.

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**Figure 1. Predicted species levels for half-degree latitude/longitude blocks of Australia from the discriminant function using all species shared between Australia and south Florida.** Blank areas have elevations greater than 500 m. Black areas are predicted as holding high numbers of species capable of invading south Florida; medium gray areas hold low numbers of species; black areas hold no species.



## LIVE TO WIN

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*International Shipping as transport vector of aquatic species.  
Results from an European-wide Research Initiative (1998-2000)*

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### **Introduction**

Until recently, the importance of ballast water as a major transfer vector that affect aquatic ecosystem stability and modify biodiversity was not generally recognised, although studies on species transfer via ballast water in maritime countries have increased world-wide. In 1998 an EU Concerted Action: Introductions with Ships (INTRO) was launched establishing a network of European scientist from 7 countries and the International Maritime Organization (IMO).

### **1. Background information**

In recent decades, ballast water discharges from ships into coastal areas have increased throughout the world, mainly occurring in or adjacent to port areas. Discharge volumes vary according to the size of vessel, type of trade and shipping routes, but are relatively high. It is estimated that the ballast water volume discharged annually world-wide exceeds 10 billion tonnes. Further estimates by the EU Concerted Action (CA) indicate that over 4,000 species are in intercontinental transit daily. The probability of successful establishment of self-sustaining populations of non-indigenous species has increased and is expected to increase further with greater volumes of ballast water carried by larger, faster ships with reduced transit times. Ships have been recognized as a major vector for the introduction of non-indigenous and harmful organisms and may thereby lead to deleterious effects on other human activities in the coastal zone.

The first accounts of species sampled from ships' ballast water were reported by Medcof (1975) followed by Carlton (1985, 1987), Hallegraeff & Bolch (1991) and Subba Rao et al. (1994). Rosenthal (1976) reviewed the state of knowledge and discussed the risks associated with transplantation of disease agents, parasites and competitive species to fisheries and aquaculture, including organisms transported in ballast water. He indicated that modern aquaculture development in the coastal zone may be at risk of disease

and parasite transfers from ballast water if aquaculture facilities and fishing areas are located in close proximity to shipping routes. The recent world-wide growth of aquaculture along shipping routes and near ports amplifies this risk, possibly rendering strict disease regulations for this industry useless in some areas.

The importance of ballast water introductions as a major vector for affecting aquatic ecosystem stability and modifying biodiversity was not generally appreciated until relatively recently. There has been a subsequent proliferation of studies on species transfer via ballast water in maritime countries across the world. However, despite considerable research effort, at both national and international scales, there has been virtually no consideration of the effectiveness or standardisation of ballast water sampling methodology. The key objective was to test monitoring systems for sampling ballast water and this was achieved by two major intercalibration workshops which compared scientific sampling techniques. These workshops delivered results allowing better comparison of ship sampling studies around the world. The second key issue are the results of the ocean-going workshops documenting the composition of organisms in ballast water during ship voyages. In addition, the effect of mid ocean exchange (MOE), which is recommended as a measure against unintentional introduction via ships, was studied. Another key objective was the public awareness campaign dealt with by the preparation of a video, a leaflet, flyer, press releases, articles to newsletters of International Aquatic Societies, Internet homepage and posters, and the case histories book providing details on eleven selected species previously introduced to European waters.

## 2. Objectives

### 2.1 Case histories

Existing literature on non-native species or ballast water research was consulted. Eleven species were selected for inclusion, ranging from unicellular algae to fish. The case histories provide background information for both the scientific and non-scientific communities. Species included: **Flora:** *Coscinodiscus wailesii*, *Gyrodinium aureolum*, *Sargassum muticum*, and *Undaria pinnatifida*. **Fauna:** *Balanus improvisus*, *Crepidula fornicata*, *Dreissena polymorpha*, *Ensis americanus*, *Eriocheir sinensis*, *Marenzelleria viridis*, and *Neogobius melanostomus*.

### 2.2 Intercalibration of ship sampling techniques

Before the ocean-going workshops commenced, the CA carried out an initial comparison of the ballast water sampling methods used by the partners within the European group during the first intercalibration workshop (summer 1998). To confirm these results and to further refine this initial exercise, a second intercalibration workshop was held in January 1999. At this workshop the ballast water sampling techniques were compared on a world-wide basis using commonly employed European and overseas techniques.

A major outcome of this exercise was the clear requirement for flexibility when sampling ships' ballast water. Different situations require different solutions, and much will depend on the specific requirements of particular studies. The subsequent choice of methods will be based on the qualitative or quantitative objectives of the study, for which the intercalibration data provided the best recommended method. The exercise demonstrated the high variability between and within methods and the virtual impossibility of obtaining a complete representation of the taxa that are present in ballast tanks. Full recovery of organisms contained in ballast tanks may remain impossible, but it is possible to strive for representative target plankton taxa for ease of comparison between studies. Larger organisms may also be sampled by the use of different collecting methods, such as light traps or baited traps.

As anticipated, the results of these experiments did not lead simply to one finally recommended sampling technique. Several methods proved to be valid elements of a hypothetical "tool box" of ship sampling techniques. The appropriate method needs to be chosen according to the selection scheme.

As new methods to sample ships may develop in the future, the undertaken study on the comparison of sampling techniques needs to be repeated as appropriate.

### **2.3 Survival of organisms in ballast water tanks during voyages (ocean-going-workshops)**

The purpose of the Ocean Going Workshops (OGW) within the CA was to examine the survival and diversity of organisms in ballast water and to compare different methods of sampling ballast water in order to allow a better comparison and interpretation of results obtained so far by independent studies carried out in the past. In addition, the effect of mid ocean exchange of ballast water (MOE), presently recommended in IMO draft guidelines and unilaterally required in some countries, as a measure against unintentional introduction via ships which are intercontinental transit, was studied. The data were obtained during five OGW, which were undertaken both in European waters (OGW 1, 2 and 5) and during inter-ocean voyages (OGW 3 and 4). In total, approximately 700 samples were collected during more than 100 days at sea.

## **3. Results**

### **3.1 Abiotic factors**

The temperature of ballast water in the tanks was similar to that of the surface seawater. Changes in seawater surface temperature were generally followed by a change in ballast water temperature with a short delay. Salinity of ballast water remains stable. Measurement of salinity in the ballast tanks following exchange with water of known salinity indicated that there was a residual amount of ballast water in the tanks that was not exchanged. Oxygen measurements showed a tendency to decline with time, but levels remained well above those required by marine organisms. The pH varied between 6.18 and 8.09. The changes may have been related to microbial activity and ballast water exchanges, but could not be correlated with any other observations made. Concentration of nutrients in ballast water was initially similar to that of the seawater pumped into the tanks. There was a steady decline in concentrations of nitrate, nitrite and phosphate. In some cases concentrations fell to below detectable levels after a few days. This may also be related to microbial activity.

The volume of total suspended sediment in the water column largely reflected the wind speed. After 8 hours of subsequent calm weather the majority of suspended material settled out of the water column. Subsequently, any rough weather conditions encountered were sufficient to re-suspend sediment throughout the water column.

### **3.2 Phyto- and zooplankton**

More species and specimens were found in new ballast water, and communities were in general similar to outside seawater. The highest number of phytoplankton species found was 52, including several potentially toxic species. At most, 40 zooplankton taxa were found in the initial samples. Abundance and diversity of phyto- and zooplankton species is fairly stable for 3-4 days, followed by an exponential decline. In some cases no living zooplankton were found after 9 days, in other cases about 10% of the taxa survived remained viable for 25 days. Sampling methods showed that in calm conditions phytoplankton exhibited vertical zonation. The layers became disrupted during rough weather and this was then associated with an increase in mortality. For the first time in ballast water studies, traps using bait and light as attractants were deployed for sampling zooplankton. Taxa not seen in the net samples were identified in trap samples.

### **3.3 Ballast water exchange**

There were two mid-ocean exchanges (OGW 3). In one, in the Indian Ocean, the abundance and diversity of zooplankton increased. The other mid-ocean exchange, in the Bay of Biscay, resulted in decreased abundance and diversity. The age of the ballast water was about the same (5-6 days) in both cases.

Some species were found in samples both before and after the supposedly complete exchange of ballast water. The decline of living marine organisms in the ballast water samples taken after the MOE was similar to that described above.

### 3. Results

- (a) Mortality of marine organisms in ballast water tanks is variable and some taxa can survive prolonged periods. Some algae, particularly toxic dinoflagellate species, have the ability to form cysts in ballast water sediments, overcoming unfavourable conditions and remaining viable for long periods. Thus, although the risk of introductions from discharge of ballast water may be minimised over longer voyages, it is not removed completely.
- (b) Although ballast water exchange is the currently recommended management method the results have shown that this will not necessarily reduce the abundance and diversity of marine organisms in ballast tanks. In some cases the same types of organisms are found in greater numbers following exchange, due to either re-suspension of residual water during exchange and/or improvement in water quality with the input of new sea water.
- (c) Further studies are needed to obtain a better understanding of changes in biota in ballast water tanks with changing conditions (including exchange) over time.
- (d) It is false to say that every species that could have been introduced would be here by now. As example there have been shipping routes from the Caspian and Black Sea region to the North American Great Lakes since many decades before the zebra mussel *Dreissena polymorpha* was finally introduced successfully to this area. It took several decades to "open" the window of introduction, i.e., to catch the right conditions in both donor and recipient areas and a vessel releasing ballast water containing a sufficient number of zebra mussel larvae at the same time.
- (e) The chance of an introduced species to become established and the chance for this introduced species to become a serious problem for the environment or economy is small. But, one single introduced species can cause severe harm to the economy and ecosystem the species invaded, as shown by zebra mussel in the North American Great Lakes, the comb jelly in the Black Sea and the green seaweed *Caulerpa taxifolia* in the Mediterranean Sea.
- (f) Our current knowledge indicates that anthropogenically supported invasions in aquatic ecosystems increase on a world-wide basis. Many other aspects of invasions remain nearly unpredictable. Among them, unfortunately, are the most wanted answers to: Which species will invade, when will it invade, where will the species invade and what will be the impact of this new species? Today these questions can be answered only on a theoretical or broad scale. Accordingly an indication of habitats at risk can be given only on a limited base. We know that certain areas such as estuaries and areas with high input of non-indigenous species (ports, waterways and shipping routes as well as aquaculture sites) represent high risk areas for further introductions. Taking into account the shipping routes and comparing matching salinity and climate conditions in donor and recipient area first incomplete estimations are possible. Adding the duration of the ships voyage (short term voyage will increase the survival rate of specimens in the ballast tank) the picture comes more clear, but still is far from a prediction and represents a kind of an advanced guess.
- (g) Management practices as (e.g. the ballast water exchange in open sea) are the first step to minimise the risk associated with species introductions. Especially in the case of the Baltic Sea and other brackish water areas, such as the Black Sea, river mouths and diluted waters of inner parts of fjords and coastal inlets, the ballast water exchange in highly marine water with oceanic salinity represents a practicable and cost effective method reducing the risk of further species introductions. Some oceanic species might, however, have the capacity to tolerate brackish salinities. On the other hand many ships may not pass such areas en route and it was indicated that the number of species may in fact increase on short routes within Europe. To follow the IMO guidelines how to ballast and how to exchange the ballast water will minimise the risk of further introductions without any re-construction of ships.

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## ESTUARIES AS A HABITAT: ON THE STATUS OF INTRODUCED MACROINVERTEBRATES ON THE GERMAN NORTH AND BALTIC SEA COAST

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### ***Introduction***

All over the world, marine and estuarine systems are subject to human-mediated invasion of non-indigenous species at an increasing rate which results in a greater uniformity of biocoenoses on a global scale. It is recognized that a number of introduced species have become numerically dominant in invaded communities and have caused damage to environmental and commercial interests.

A basic requirement for a proper processing of measures, which should lead to a minimization of man-induced spreading of species, is a comprehensive analysis of the phenomenon "bioinvasion". The scope of this contribution is to evaluate the significance of different human-mediated vectors and the reasons for successful establishment with the example of introduced macrozoobenthic species in German coastal waters of the North and Baltic Sea.

### ***GERMAN NORTH SEA COAST***

In total, 26 recently established macrozoobenthic species were identified as introduced on the German North Sea coast. The main area of origin is the Atlantic coast of North America (9 species). In general, non-indigenous species only became established if they were introduced from similar latitudes. The main vector was the transport by fouling on ship hulls (example: barnacle *Elminius modestus*). Also the transport in ballast water tanks (example: American jack knife clam *Ensis americanus*) as well as deliberate commercial introductions (example: Pacific oyster *Crassostrea gigas*) and associated unintentional forms by these imports (example: slimper limpet *Crepidula fornicata*) were important vectors (Fig. 1). The intentional release play a subordinate role. On account of the limnic barriers the coastal faunal replacement through canals is insignificant. Up to now only three Pontocaspian species (example: amphipod *Corophium curvispinum*) as well as one Mediterranean species (isopod *Proasellus coxalis*) arrived the brackish areas of the North Sea estuaries.

The share of the introduced species compared to the respective total macrozoobenthic species numbers amounts to 1% in the open German Bight of the North Sea, 3% in the Wadden Sea, 10% in the brackish water zone of the estuaries of the rivers Elbe, Ems and Weser and 7% in the brackish canals and ditches. However, no relevant ecological or economic effects of the non-indigenous macroinvertebrates could be shown for the German North Sea coast as yet. They become integrated and lead to an increase in the number of species.

### *GERMAN BALTIC SEA COAST*

Recently 15 macrozoobenthic species have been identified as introduced on the German Baltic Sea coast (Fig. 1). It seems that only the polychaete *Marenzelleria viridis* was directly introduced by ocean shipping. All other species either come from the Pontocaspian and are transported through canals with inland waterway crafts or were at first introduced into the North Sea and transported from here through the Kiel Canal or by natural drift in water currents to the Baltic. At present two North Sea species (example: amphipod *Corophium multisetosum*) are considered as introduced on the German Baltic Sea coast, because they arrived in this area through the Kiel Canal.

The share of the introduced species compared to the total macrozoobenthic species numbers amounts to 3%. Relevant ecological and economic damages by introduced macroinvertebrates are not known on the German Baltic Sea coast as yet. Also mass forms as e.g. the polychaete *Marenzelleria viridis* did not apparently replace any native species. The relatively distinct bioturbation of *M. viridis* could have effects on the biogeochemical cycle, although without consequences for the entire Baltic Sea.

#### *ESTUARIES: THE HABITAT FOR INTRODUCED MACROINVERTEBRATES*

It is striking that most of the introduced macroinvertebrates have established permanent populations in the German North Sea estuaries (19 species in total). Several reasons are probably responsible for this:

1. Salt-tolerant limnic species, which were transported through canals with inland crafts, reached the coast first in the estuaries (currently four species, see Fig. 1).
2. The estuaries are characterised by intense intercontinental shipping and have a higher potential infection rate also with the background, that ballast water often has estuarine character.
3. About half of the introduced macroinvertebrates in the estuaries are genuine brackish water species, which have a high tolerance for changing environmental conditions and by this have a better chance of being transported alive than euhaline species.
4. Of considerable importance is the natural autochthonous species minimum in the brackish water zone of estuaries, i.e. many vacant ecological niches are present. Because of this it is easier for an introduced species to establish itself there.

#### *Conclusions*

Even if no relevant ecological and economic effects by introduced species could be found as yet in the German coastal waters, on international level the need for action concerning the minimization of organism introduction by the transportation vector ocean shipping has been recognized for some years. Among others, different sterilisation methods for ballast water were checked for their effectiveness, e.g. irradiation with ultraviolet, ultrasound and microwaves. However, no method could be found yet, which is technically feasible on a large scale, safe, cost effective and compatible to the environment. An ecological mild method would be the exchange of ballast water on the high seas as required by the MEPC of the IMO London. But investigations have shown that as a result of this method the introduction of organisms can only be minimized in a limited manner.

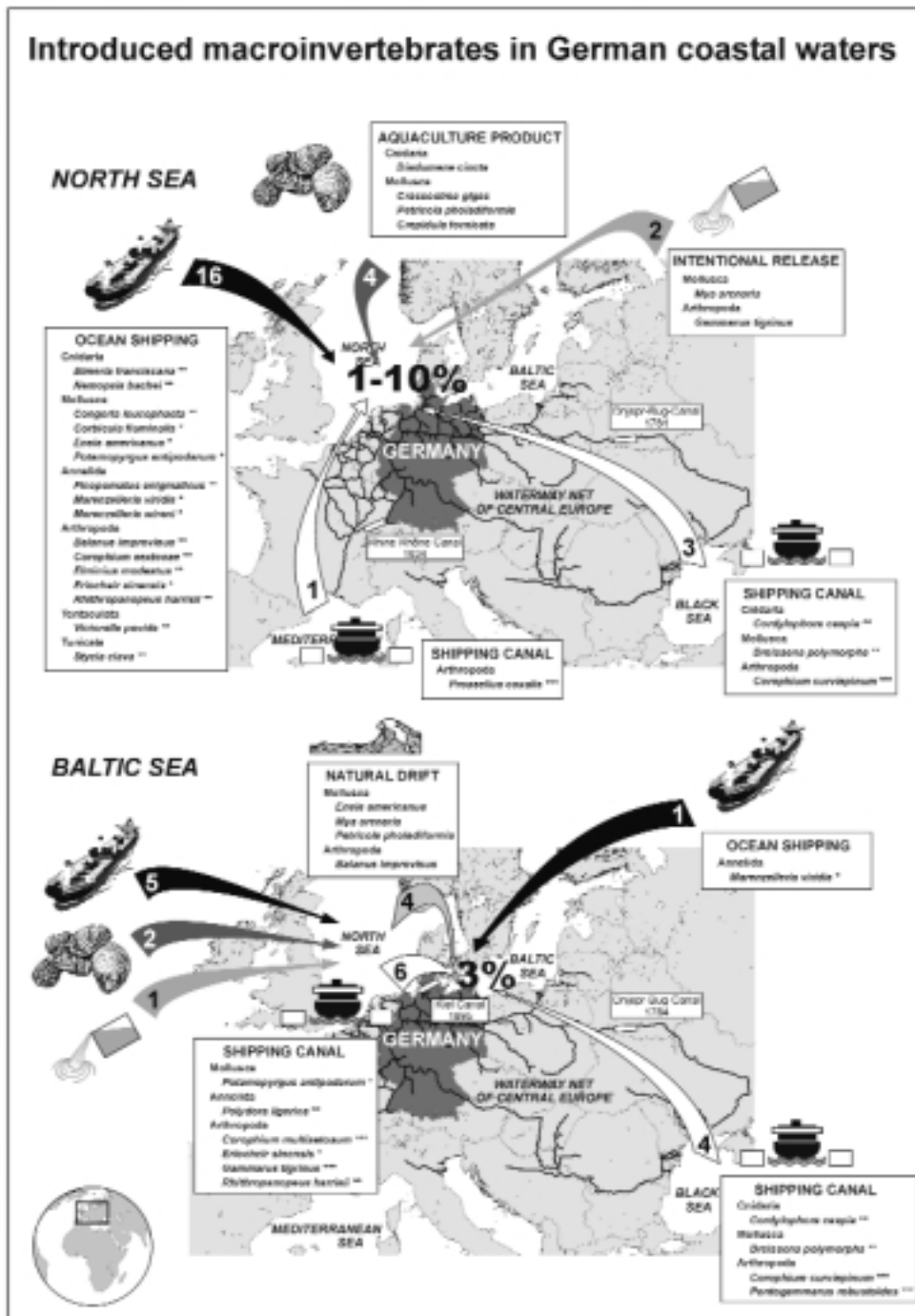
However, it is very likely that the discussion about the vector ballast water misjudges much more important threats. A recent summary by Nehring (2001) about the introduction vectors of non-indigenous species in the entire North Sea revealed that phytoplankton and phytobenthos species are mainly introduced in association with aquaculture products (especially oysters). The majority of introduced faunal species have reached the North Sea (as well as the German North Sea coast, see above) by transportation on ship hulls. These findings show that the development of ecologically acceptable methods for the prevention of fouling on imported aquaculture products as well as on ship hulls is much more important. In this context, due to the proposed IMO ban of the harmful but effective biocide tributyltin in ship antifoulants, the pathway of invasive species introductions via ship fouling can attain a new dimension worldwide.

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**Fig. 1:** Introduced macrozoobenthic species on the German North and Baltic Sea coast. Known or probable introduction vectors (\* ballast water, \*\* hull, \*\*\* hull or active migration), number of introduced species and their amount on total species number (in percent), important canals and their opening date. For further explanations, see text.





## MODELING THE EVOLUTIONARY CONSEQUENCES OF SPECIES INVASIONS: CAN NATIVE PREY ADAPT IN TIME TO AVOID EXTINCTION?

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**Keywords:** *predator invasions, rapid adaptation, marine ecology, gene flow, evolution*

### ***Background***

Ecological effects of invading predatory species, such as crowding competition and displacement of native organisms have been well studied and are known to be important both economically and ecologically. Evolutionary effects of invasive predators such as causing life history changes or extinctions are less well known. Endemic prey species may not be able to evolve defenses against specialized predator and will go extinct unless they can quickly adapt. Rapid adaptation due to predators has been shown to cause changes in life history traits as quickly as 18 generations in experiments with guppies (Resnick 1997). In field experiments that have dealt with predator prey interactions, removal experiments are more common than introductions (Sih et al. 1985).

### ***Study System***

This work entails the addition of predatory shore crabs (*Hemigrapsis nudus*) to wave exposed rocky intertidal shores near Bamfield Marine Station on Vancouver Island, British Columbia, where they do not naturally inhabit by building shelters for them. We are in the process of developing techniques to monitor demographic and population parameters to predict whether local snail populations (*Littorina* sp.) will go extinct after the invasion using a model developed by Boulding and Hay (in review). These shore crabs have been found to selectively prey on thinner shelled snails, and forage mainly within 3-5 meters of their shelters. If, after adding crabs to selected field sites we can to monitor parameters described below, we can predict the fate of the prey. These parameters are: prey population size, prey population growth rate, heritability of a quantitative trait under selection (shell thickness in this instance), phenotypic variance of that trait, the strength of selection by the predator, and gene flow from neighboring prey populations subject to different selection pressures. The techniques to measure the first four parameters are well established in this system. The present research focuses on development of techniques to measure the later two parameters in order to be able to manipulate the system and monitor the evolutionary changes in the prey after the additions of predators.

### ***Preliminary Findings***

We have found that the strength of selection is dependant on the predator size and needs to be measured separately for each invading size class in order to get an accurate idea of the intensity of selection pressure (Figure 1). The large crabs are less selective on shell thickness than the small crabs. Using this information we can manipulate the selection pressure experimentally by adding large or small crabs to various sites, and monitoring population changes. We have also found that the snail neighborhood size (Figure 2), or the lifetime dispersal distance, is roughly the same area as the crabs foraging range around their shelters (about 3-5 meters) (Boulding, unpublished data). We hypothesize that local adaptation may be constrained by migration from other snail populations experiencing different selection pressure. Future experiments will focus on this aspect and will attempt to highlight which parameters are most

important in determining whether local native populations will adapt or go extinct after the invasion of an exotic predator. This work will allow the testing of current models in predicting the evolutionary effects of invading organisms in the intertidal as well as other ecosystems subject to invasions, which are becoming more common because of human activity.

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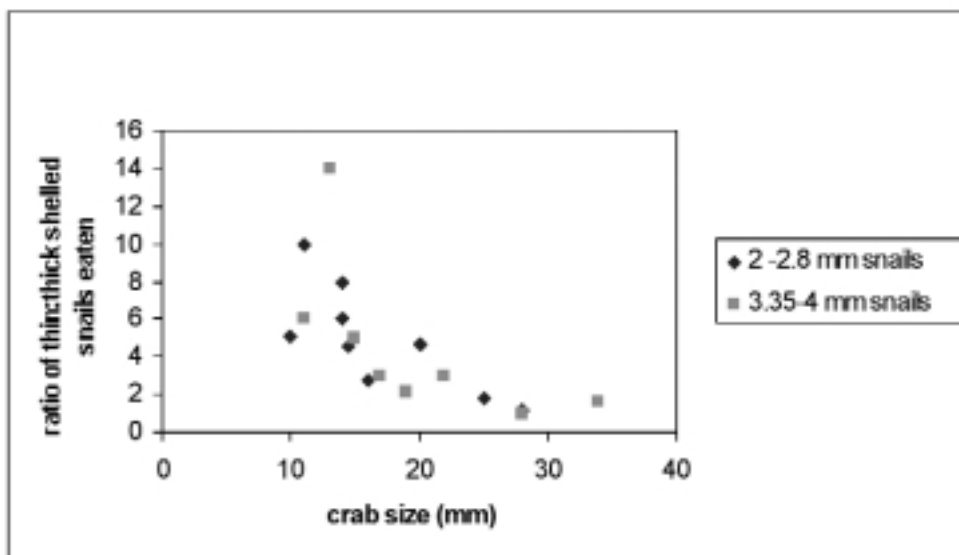
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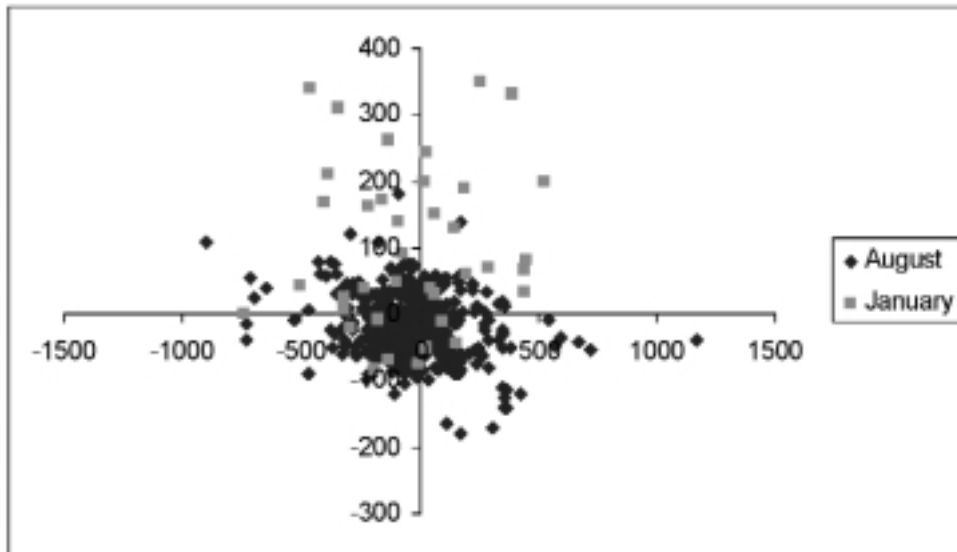
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**Figure 1: Relationship between selection on shell thickness and predator size.** Crabs (*Hemigrapsis nudus*) were fed equal numbers of thin and thick shelled snails (*Littorina subrotundata*, and *L. sitkana* respectively) of similar size class in the laboratory. Y-axis values represent ratios of thin to thick shelled snails eaten. For example, a value of 10 means that a crab ate 10 thin shelled snails for every 1 thick shelled snail eaten. Larger ratios indicate more intense selection for shell thickness.



**Figure 2:** The movement of prey: *Littorina subrotundata* were released in May 2000, and recaptured in August of the same year and the following January, on wave exposed shores at Nudibranch point, in Barkley Sound British Columbia. The x-axis lies parallel to shore and falls at the midpoint of the *Littorina* distribution in the intertidal (3.5-4m above 0 datum). Positive values on the y-axis lead away from the ocean, and negative values are toward the ocean. The neighborhood size, calculated using the median distance traveled in the x direction multiplied by 2.8 (Wright, 1969), is equal to about 2 meters after 3 months and about 5.5 meters after 7 months.





## TRACKING SOURCES, PATTERNS, AND EFFECTS OF COASTAL MARINE INVASIONS

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The Smithsonian Environmental Research Center (SERC), located on the shore of Chesapeake Bay, is a national center within the U.S. for research in the area of non-native species invasions in coastal ecosystems. A primary goal of SERC's Marine Invasion Research Laboratory is to provide the fundamental science that is critical to develop effective management and policy in this topic area.

As a national center, SERC's Marine Invasion Research Laboratory provides synthesis, analysis, and interpretation of invasion-related patterns for the country. Under the National Invasive Species Act of 1996, the U.S. Coast Guard and SERC created the National Ballast Water Information Clearinghouse to collect and analyze national data relevant to coastal marine invasions. Established at SERC in 1997, the Clearinghouse measures:

- **Nationwide Patterns of Ships' Ballast Water Delivery and Management.** All commercial ships arriving to all U.S. ports from overseas report information about the quantity, origin, possible control measures for their ballast water - a primary mechanism for transfer of non-native marine species throughout the world. SERC is expected to receive roughly 60,000 such reports per year. Every two years, SERC provides a detailed analysis and report to U.S. Coast Guard and Congress on the patterns of ballast water delivery by coastal state, vessel type, port of origin, and season. A key issue is the extent to which ships undertake ballast water exchange, a management technique to flush potential invaders out of the tanks prior to arrival in U.S. waters. This analysis is used by U.S. Coast Guard and Congress to assess national needs with respect to ballast water management.
- **Rates and Patterns of U.S. Coastal Invasions.** SERC has developed and maintains a national database of marine and estuarine invasions to assess patterns of invasion in space and time. This database compiles a detailed invasion history of approximately 500 different non-native species of plants, fish, invertebrates, and algae that have invaded coastal states of the North America. Among multiple uses, the database identifies which species are invading, as well as when, where, and how they invaded; it also summarizes any existing information on the ecological and economic impacts of each invader. Over the long-term, this database will help assess the effectiveness of various management strategies (such as ballast water management, above) in reducing the rate of invasions. More broadly, this information is a valuable resource for many user groups --- from resource managers and scientists to policy-makers and industry groups.

At the core of each component is an extensive database. These two databases are designed explicitly as research and management tools to:

- Characterize patterns of invasion in space and time according to species, taxonomic group, transport mechanism (or vector), habitat, latitude, and a suite of biological characteristics;
- Identify ecological and economic impacts of known or potential invaders;
- Develop predictions and risk analyses about patterns and effects of invasion, based upon empirical data (above);
- Evaluate management strategies to prevent invasions by particular species and vectors.

Importantly, the two databases are designed to operate synergistically. The database of established invaders is used for vector analysis, identifying the relative strength of various vectors in space and time. Analysis of current data indicates that shipping has been responsible for most marine invasions in the United States, the rate of new invasions appears to be increasing, and this increase is driven largely by the shipping vector (Ruiz et al. 2000). The role of shipping and the apparent increase in invasion rate has also been reported for a number of individual estuaries within the U.S. (e.g., Mills et al. 1993, Cohen and Carlton 1998, Ruiz et al. 2001). Ships are now being asked to implement management strategies, including ballast water exchange and alternative technologies, to reduce the risk of future invasions. The database on shipping serves to characterize the immediate effectiveness of this program, tracking the rate of compliance and types of management strategies used, whereas the database on reported invasions is designed to measure the long-term response in the actual rate of invasions. This latter aspect is key to assessing the efficacy of management activities and providing feedback for future management and policy decisions.

A fundamental obstacle in measuring patterns and rates of invasion, however, has been the lack of standardized surveys, to provide robust baseline data (Ruiz et al. 2000). SERC has initiated a program of field surveys to detect new invasions, as well as measure contemporary patterns of invasion, for 15-20 different bays throughout the country (Figure 1). Our intent is to expand this program to include additional regions in and outside of North America, establishing core sites for intensive and long-term measures. Toward this end, we have initiated surveys in Australia and have begun to pursue parallel measures through collaboration in other countries.

More broadly, we wish to develop an international network of collaborators, to build complementary and comparative measures of invasion patterns and vector operation. Such a network would greatly enhance information needed for both management and understanding of invasion processes. A key tool in building such a network is the creation and interaction of parallel databases, expanding access to information across many geographic regions, habitat types, and taxonomic groups.

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Figure 1. SERC Marine Invasion Survey Sites





## ALIEN SPECIES: EXPERIENCES AND LESSONS LEARNED IN BIOSPHERE RESERVES

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***Keywords: biosphere reserves, alien invasive species, cooperation,  
peoples, emerging ecosystems***

### ***Context***

Under UNESCO's intergovernmental Man and Biosphere (MAB) programme, 391 sites in 94 countries currently constitute the World Network of Biosphere Reserves, some of which are, due to the transboundary nature of their ecological features and problems they face, shared between two or more countries.

Biosphere reserves aim at putting the ecosystem approach into practice, while reflecting the specificity of inhabitants and their environment. They act as 'living laboratories', testing scientific hypotheses and developing new ecological theories through integrated research (which also contributes to the Diversitas programme) and monitoring (within the Biosphere Reserve Integrated Monitoring (BRIM) programme).

Many biosphere reserves have reported alien species and launched programmes to prevent, eradicate or contain these species within confined areas.

### ***Experiences***

This poster will review biosphere reserves and the problems associated with alien species and, based on several case studies, will present some experiences and lessons learned.

One case study refers to the Kogelberg Biosphere Reserve (South Africa) and its unique fynbos vegetation that is threatened by invasive trees and shrubs. It will point out the importance of maintaining the biodiversity in the Western Cape Province particularly in economic terms.

Studies in the Hawaiian Islands Biosphere Reserve (U.S.A.) prove that some invasive plants are not only able to dominate over native plant species, but can also have a lasting effect on the biome.

The Archipelágo de Colon Biosphere Reserve (Galápagos, Ecuador) has reported an alien vertebrate that seems to have adapted to an ecological niche not inhabited by native species, thus exemplifying that alien species are not necessarily invasive.

The Biosphere Reserve of Astrakhanskiy (Russian Federation) provides an example of a "new" or "emerging" temperate wetland-delta, pointing out impacts of irreversible transformations on natural vegetation and freshwater ecosystems.

*Lessons learned and other conclusions*

The poster concludes by summarizing lessons learned and practices used in biosphere reserves, with an emphasis on those that can be applied beyond the sites studied. The presentation points out that our understanding towards impacts and consequences caused by alien species on ecosystems needs to go further than prevention, eradication and control measures. Those mechanisms do not comprise the central aspect of emerging ecosystems, for which different measures to deal with invasive species may be needed. Once an alien species has irreversibly invaded an area, we have to accept its presence as an integral part of an emerged ecosystem rather than considering the ecosystem as altered in a negative way.

## ERADICATION OF ALIEN MAMMALIAN PREDATORS IN THE SEYCHELLES IN 2000

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**Keywords:** *eradication, domestic cat, brown rat, black rat*

### *Alien Mammals in the Seychelles*

The Seychelles is an Archipelago of 115 islands in the western Indian Ocean comprising of 75 outer or coralline islands and 40 inner or granitic islands. This case study is specific to the inner islands.

Fourteen species of alien mammal have established feral populations; thirteen are extant on the islands although eight have displayed range contractions. Most species are restricted range and only Domestic cat (*Felis catus*), Black rat (*Rattus rattus*) Norway rat (*R. norvegicus*) and House mouse (*Mus domesticus*) occur on more than four islands.

The target species of the eradications, which took place in 2000, are two rat species, Black rat and Norway rat and Domestic cat. House mice were not classified a target but their extirpation during rat eradication was considered to be desirable. Rodent introductions have been presumed to occur from boat traffic, specifically within cargo. This is supported by two recent introduction events that coincided with resort redevelopment and increased cargo traffic.

Merton (1999a), working with Ministry of Environment and Transport (MoET), assessed rat and cat populations on five islands through systematic trapping in July/August 1998. He also conducted palatability trials of various types of poison bait upon target and non-target species. The data collected were used as a basis for drawing up rat and cat eradication strategies for each of the five islands (Merton 1999b).

### *Options considered to address the problem*

In 1995 a private operation to eradicate Black rats from Bird Island using a ground application of bait was successful (Merton 1999a). A ground based programme that attempted to halt colonisation of Frégate failed due to a range of factors. This stimulated interest in rodent eradication and in 1998 an assessment of eradication potential was conducted and a plan proposed (Merton 1999a). MoET established an “eradication steering committee”; ultimately three islands were included, Curieuse, Denis and Frégate.

The risks to non-target species were thoroughly examined. Ground feeding birds were at most risk. Endemic Seychelles Magpie robin *Copsychus sechellarum* and Seychelles fody *Foudia sechellarum* had to be managed in captivity on Frégate. Aldabran Giant tortoise (*Geochelone gigantea*) had to be corralled on Curieuse, Frégate and Denis.

There was broad agreement by all stakeholders to eradicate rats through the aerial application of the anticoagulant Brodifacoum. Ground baiting was not possible due to island size and accessibility. A combination of trapping and 1080 bait was employed on cats.

MoET acted as overall co-ordinator and acted jointly with the Marine Parks Authority (MPA) for activities on Curieuse, provided implementation teams on Denis and support for eradication teams. Private island owners liaised with MoET and eradication teams. BLS managed captive landbirds on Frégate.



### *Implementation of Measures*

Implementation has been divided into four phases with key tasks identified below:

- (a) Equipment and personnel: Specialist equipment e.g. baits sourced and imported by eradication team. Islands sourced and imported materials for example tortoise pens. Staff recruited, pilot and support team, avian vet and aviculturalist.
- (b) Preparation: Materials in place, rodent monitoring initiated, resort closure, improved food and waste management, wildlife capture and holding.
- (c) Eradication activities: Meteorological monitoring, bait application and additional hand baiting in enclosed areas. Cat trapping and poisoning commenced.
- (d) Post Eradication: Monitoring of bait application, consumption and degradation, captive population release, long term monitoring of threatened species. Establishment of reintroduction protocols.

Twelve months should elapse before a declaration of success. Early indications suggest that *Rattus* Spp. have been eliminated on all three islands. The status of mice is uncertain. Cat eradication on Denis and Curieuse is scheduled to continue until mid-2001. A very small number of cats are believed to persist on Dennis, but eradication may have been achieved on Curieuse. A moderate impact was recorded on some alien bird populations. No evidence of damage to invertebrate populations was found. Post-release survival and breeding success of the Seychelles magpie robin has been high.

### *Lessons learned*

Complete commitment of primary stakeholders essential to success. Sound bureaucratic support is essential specifically in regard to permissions and financing. The gathering of robust scientific evidence is desirable to counter public concerns. Island based eco-type tourism provide an incentive to clear and maintain islands predator free. Relic populations of endangered faunal communities inflate costs and tourist activities increase risks of re-infestation. Alien species abatement measures need to be drawn up and implemented and enforcement may be required.

This provides evidence that rodents prevailing in tropical ecosystems are more susceptible to rodenticide application than previously believed. Replication on further inner islands is probable. Replication on the outer Seychelles is possible but more logistically difficult and expensive.

Information dissemination is ongoing, via the CBD case study, Seychelles Magpie robin recovery programme reports, Proceedings of IUCN's ISSG Eradication of Island Invasives Conference (2001) and a captive management technical report. Non-technical publications are also in prep.

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## THE THREAT TO NORTH AMERICAN FORESTS FROM PESTS INTRODUCED ON WOOD PACKAGING

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***Keywords: forest biodiversity; alien insects; solid wood packing material (SWPM)***

### ***U.S. and Canadian Forests Are Vulnerable To Alien Pests***

The forests of the United States occupy 298 million ha. They contain irreplaceable biological diversity — tens of thousands of species. Repeated invasions by alien species have radically altered forest species composition and pushed species of both trees and dependent organisms to the brink of extinction.

### ***Examples of Trees Severely Depleted by Alien Pests***

American chestnut (*Castanea dentata* (Marsh.) Borkh) once made up a quarter of the trees in the forests cloaking the Appalachian Mountains. The chestnut blight (*Cryphonectria parasitica* (Murr.) Barr) — a pathogenic fungus quickly killed nearly all the chestnuts throughout its range. This loss eliminated an important wildlife food source and increased erosion. The forest has not fully recovered (Campbell and Schlarbaum, 1994).

The Fraser fir (*Abies fraseri* (Pursh.)) is a narrowly endemic species found only in a National Park. An introduced aphid, the balsam woolly adelgid (*Adelges piceae* (Ratzeburg)) has killed nearly all the mature Fraser firs. The changed forest structure has altered bird species composition and endangered two other endemic species (Alsop and Laughlin, 1991).

The whitebark pine (*Pinus albicaulis* Engelm.) occupies high mountain ridges in the West. It is an essential food source for wildlife, including grizzly bears. An introduced fungus, white pine blister rust (*Cronartium ribicola* J.C. Fisch.), has killed more than 90% of the whitebark pines in a National Park and nearby regions (Campbell and Schlarbaum, 1994). The USDA Forest Service has begun a restoration program (Matthews, 2000).

### ***Wood Packaging — A Dangerous Introductory Pathway***

U.S. and Canadian officials have determined that wood packaging material — pallets, crates, wooden spools for cable, and dunnage (defined) — is a major pathway for introduction of forest pests. Phytosanitary inspectors report that the vast majority of alien insect species that threaten the forest have been detected on wood packaging (Williams and La Fage 1979; Haack and Cavey 1997; USDA APHIS and FS 2000; [www.cfia-acia.agr.ca/english/plaveg/for/evaluae.shtml](http://www.cfia-acia.agr.ca/english/plaveg/for/evaluae.shtml)).

Wood packaging is an especially dangerous vector for pests because (USDA APHIS and FS 2000):

- approximately 50% of imported shipments contain wood packaging — far too many to be examined;
- phytosanitary agencies cannot predict how risky any one shipment is — or set priorities;
- the wood conceals any hitchhiking pest;
- pests hitchhiking on wood packaging can be transported anywhere in the country;
- the practice of reusing wood packaging provides additional opportunities for pests to mature and escape.

The risk assessment conducted by the U.S. Department of Agriculture concludes that inspection is not an effective measure to prevent the introduction of alien forest pests hitchhiking on wood packaging (USDA APHIS and Forest Service 2000).

While attention has focused on pests that originated in China, wood packaging from all trade partners pose a threat to U.S. and Canadian forests. In recent years, U.S. and Canadian inspectors have detected insect pests on wood packaging from more than 60 countries (USDA APHIS and Forest Service 2000; [www.cfia-acia.agr.ca/english/plaveg/for/evaluae.shtml](http://www.cfia-acia.agr.ca/english/plaveg/for/evaluae.shtml)).

Provide brief descriptions of the following pests that have been introduced or intercepted on wood packaging: Asian longhorned beetle, brown spruce longhorned beetle, Eurasian spruce beetle and Sirex woodwasp. All four threaten widespread and significant damage to these countries' forests.

### *Protective Efforts*

Canada plans to strengthen and broaden its inspection program targeting wood packaging; pursue prompt implementation of a regional standard by the North American Plant Protection Organization (NAPPO); and champion adoption of an international standard by the International Plant Protection Convention (IPPC).

The United States has worked with Canada and Mexico within NAPPO and with all parties within in the IPPC to develop international standards for wood packaging. Describe proposals briefly. The United States is also developing stronger national regulations that might require all trading partners to treat wood packaging or use substitute materials that are unlikely to harbor pests.

Among the difficulties facing those developing both national and international safeguards are the increased costs that treating wood packaging would impose on shippers and reconciling treatment measures with other international obligations. For example, fumigation of wood packaging using methyl bromide is relatively inexpensive — but expanding use of this chemical violates the goals of the Montreal Protocol on Ozone-Depleting Chemicals.

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## ALIEN INVASIVE PLANTS IN BANGLADESH AND THEIR IMPACTS ON THE ECOSYSTEM

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**Keywords:** *Invasive plant, Bangladesh, Ecosystem, Inhibit, Weed.*

The study describes the name of some important invasive alien species and their impacts on the ecosystems so far known to occur in Bangladesh. More than 300 exotic species are supposed to either wildly growing or cultivated as an economic crop in Bangladesh. Of them, the herbaceous and lianas are the dominant exotics followed by trees and shrubs.

Plant introduction is a very time old practice and over a long period, plants of various types of economic importance were introduced in this country (Islam, 1991). Migration or introduction of plants from one place to another may be natural or planned one. Bangladesh, like many other countries have a long history of plant introduction from different countries or geographic areas of the world. Most of the plants have brought by settlers, invaders, seamen and traders. In Bangladesh, there are no detail records of exotic plants except the plants of some common and few cultivated ones. Many of the exotic plants are considered as extremely economic and some are vital useful as a cash crop. Some of the very common fruit trees like litchi (*Litchi chinensis*), pineapple (*Ananas sativus*), watermelon (*Citrullus lantus*), coconut (*Cocos nucifera*) and guava (*Psidium* sp.) are also introduced. Most of the pulses and oil yielding plants are also exotic. Many important vegetables like cucurbits (*Cucurbita* spp.), radish (*Raphanus sativus*), potato (*Solanum tuberosum*) and carrot (*Daucus carota*) are also came from other countries and became naturalized throughout the country.

However, a good number of exotic plants are weedy in nature. Most of them were first introduced as garden or ornamental plants and later on aggressively established elsewhere. Some of them are so well established that they are now the dominant plant and became noxious weeds of forests and wastelands (*Eupatorium odoratum*, *Mikania cordata*, *Croton* sp. etc.). Some are considered as noxious weeds of cultivated fields also (*Alternanthera*, *Scoparia* and *Heliotropium* spp.). Some troublesome weeds are also found in water land (*Eichhornia*, *Eleocharis* and *Monocharia* sp.).

In 19th century the British people were mostly contributed to the introduction of some economically important forest plants from almost all the continents. The introduced species are *Tectona grandis*, *Albizia* spp., *Samanea saman*, *Xylia kerrii*, and *Swietenia macrophylla*. In the 20th century this trend continued to be the same, and some Australian species (*Eucalyptus camaldulensis*, *Acacia mangium*, *Acacia auriculiformis*) are getting preferences in the plantation programs. *Leucaena leucocephala* (Tropical America) are also found all over the country and pines (*Pinus oocarpa* and *P. caribaea*) are also planting in the hilly areas (Das, 1982). Of these, the *Acacia auriculiformis* is dominating in all the plantation programs and growing well in all sorts of degraded land. Recently, the controversy arises that the pollen of the species is allergic to many peoples! Very recently, the cultivars and hybrids of different crops and ornamental plants are also introduced haphazardly.

Some weedy species dominate crop fields, forests, wasteland and marginal lands. Some of the species have luxuriant growth and suppressed the growth of other native species (Table 1). This results in a loss of native floral diversity of the country. The threat posed to natural habitats by these alien invasive plants is becoming a major concern among the conservationist, ecologist, foresters, policy makers and scientists. Though the undisturbed natural forests are resistant to such invasion, but the degraded and secondary forest areas and wastelands are aggressively invaded by the invasive species.

To prevent the adverse impacts of invasive plant species to the natural ecosystem, the possible suggestion is that I) enhancing awareness among the planters, growers and publics; II) development of database on invasive species; III) quantify the abundance of the species; IV) development of environmentally sound eradication methods and V) introducing the necessary quarantine, legislation and regulations on the spread of the invasive plants.

**Table 1: Alien exotics in Bangladesh which have a detrimental impact on the ecosystem.**

Scientific Name	Family	Origin	Impact on the ecosystem
<i>Acacia auriculiformis</i>	Mimosaceae	Australia	Widely planted in afforestation programs, but controversy over pollen allergy!
<i>Eucalyptus camaldulensis</i>	Myrtaceae	Australia	Promising growth performance in experimental plantations, but now ban due to its controversial impact on environment.
<i>Leucaena leucocephala</i>	Mimosaceae	Tropical America	Occasionally cultivated; wild in coastal areas; suppressed the regeneration of other species
<i>Acanthospermum hispidum</i>	Asteraceae	South America	Common weed of cultivated fields
<i>Cassia occidentalis</i> L.	Caesalpiniaceae	Tropical America	Common weed of wasteland and road side
<i>Cestrum diurnum</i> L.	Solanaceae	Tropical America	Weed of road side and rail line
<i>Lantana camara</i> L.	Verbanaceae	Tropical America	Common weed of hilly areas, prevent regeneration of native species
<i>Ageratum conyzoides</i> L.	Asteraceae	South America	Common weed of waste and cultivated field; aeroallergic pollen species
<i>Alternanthera flocoidea</i> (L.) R. Br.	Amaranthaceae	Brazil	Common weed of cultivated and waste land
<i>Atylosia scarabaeoides</i> Benth.	Fabaceae	Australia	Common weed of wasteland
<i>Eupatorium odoratum</i> L.	Asteraceae	Central South America	Common weed of wasteland; suppressed the regeneration of other species in plantation programs
<i>Commelina obliqua</i> Buch.-Ham.	Commelinaceae	Java	Frequent weed in wasteland
<i>Convolvulus arvensis</i> L.	Convolvulaceae	Europe	Frequent weed of waste place
<i>Croton bonplandianum</i> Baill.	Euphorbiaceae	South America	Abundant weed of waste and cultivated land

Eichornia crassipes (C. Martius) Solms.	Pontederiaceae	Tropical America	Abundant aquatic weed; aggressive growth inhibits other aquatic flora
Evolvulus nummularius (L.) L.	Convolvulaceae	West Indies	Common weed in cultivated and open fields.
Hyptis suaveolens (L.) Poit.	Lamiaceae	Tropical America	Common weed of hilly regions
Ipomoea carnea Jacq.	Convolvulaceae	America	Common weed of all habitat
Ludwigia adscendens (L.)	Onagraceae	Central America	Common weeds in aquatic and marshy habitat
Mikania cordata (Burm. f.) Robinson	Asteraceae	Tropical America	Abundant weed of forest and wasteland; engulf other economic crops by its luxuriant growth
Mimosa pudica L.	Mimosaceae	South America	Common weed of cultivated and waste land

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## IMPACT OF INVASIVE SPECIES ON BIODIVERSITY CONSERVATION AND POOR PEOPLE'S LIVELIHOODS

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***Keywords: invasives; conservation; disturbance; people's livelihoods; collection of non-timber-forest-products***

Invasive species is an increasingly important disturbance factor throughout the world's humid tropical forests. It affects the species composition and the spatial distribution of plants and animals. Thereby, it affects the availability of natural forest resources, such as non-timber-forest products, to people who live in, and who are entirely dependent upon the resources found in, forests. People strongly dependent upon local forest resources will be more affected by of a changing spatial and temporal distribution in forest resources, than people who are less dependent on those resources.

Indigenous people living in the interior parts of the forest away from developed infrastructure, and hence often having few or no alternative income sources/options are therefore more sensitive to, i.e., more likely to be affected by, changes in the availability of local natural resources (such as non-timber-forest-resources). Invasive species can affect the availability of local forest resources both through direct and indirect mechanisms.

Throughout the humid tropics, highest concentrations of native and endemic biodiversity tend to occur in the interior of forests. These areas also tend to be critical for the existence of many indigenous peoples. Such is indeed the case in the Western Ghats (in southern India), a global biodiversity hot-spots. Suitable strategies are needed to conserve the forest and its biodiversity while ensuring a sustainable resource base for indigenous groups, Soligas, that have long inhabited the area.

The causes for and the impact of increasing invasive species abundance are complex and of interdisciplinary nature, involving ecological, social, and economic issues, and interactions between them. Figure 1 illustrates a general conceptual model of how invasive species may affect conservation of biodiversity and local people's livelihoods.

The spatio-temporal distribution and composition of biodiversity, and local forest resources in general, can be affected directly by the invasive species (due to predation, herbivory, parasitism, pathogens, and competition). This may cause a change in the local people's utilization (such as extraction) patterns (spatially and temporally) of the local forest resources. Finally, there may be a feedback impact of the changed spatio-temporal utilization patterns on the spatio-temporal distribution and composition of the natural resources, either directly or indirectly (the latter through its impact on the biophysical processes). This diagram is very simplistic and emphasizes the general similarity between invasive species and any other human disturbance with effects across a wide range of spatial scales.

The goal of the present study was to understand how invasive species, in particular Lantana, affected local people's livelihood and conservation of forest biodiversity, in a forest area in southern India. The research presented in this paper represents initial efforts within a broader and integrated research program on the impact of disturbance and fragmentation on biodiversity and local people's livelihoods, in an area in southern India. The objectives were to examine a) the effect of Lantana cover on the area used by Soliga people, b) the effect of Lantana cover on median walking distance for collection of NTFPs, c) the relationship between human disturbance intensity and the density of Lantana, and, d) the effect of density of Lantana on natural regeneration of woody plant species.



Eight Soliga settlements in total, two in each of the four major vegetation types, were used for this study. Each settlement was located entirely within the given vegetation type (i.e., the minimum distance from any settlement to the boundary of the given vegetation type was at least one kilometer).

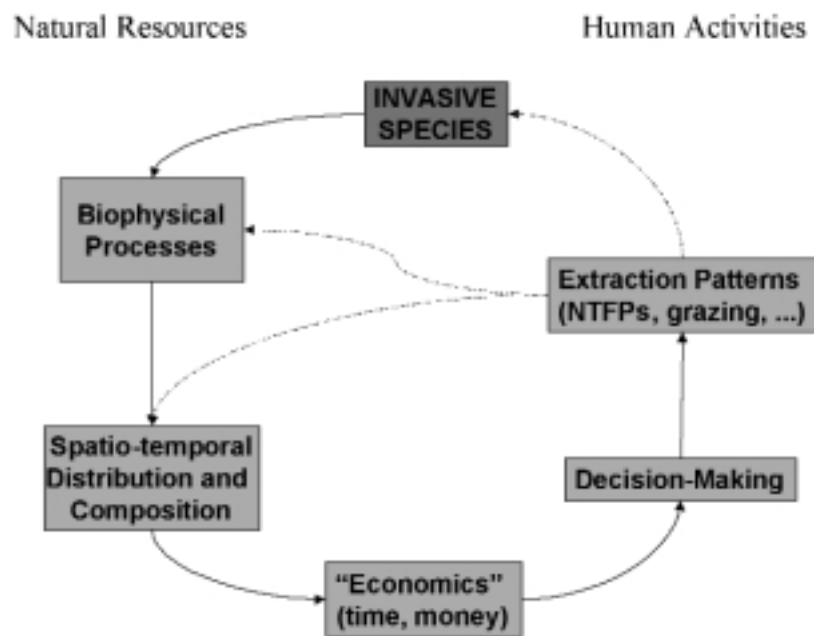
In each vegetation type and starting from the settlements (Podus) to the undisturbed (relatively undisturbed) forest, one plot for each of five disturbance levels, ranging from the most disturbed (level 1) to the least disturbed (level 5) laid on the settlements were considered. All other transects (levels 2, 3, and 4) were placed on a "scale" between the first and the fifth levels. This scale followed a distance or topographical measure, because it is assumed that the human impact decreases as we go away from the settlement into the forest and also the presence of topographical barriers. The location of areas for each disturbance level was selected based on interviews with the Soliga people in each settlement, and we collected information on a) number of households, population of the podu (approximate number), b) expanse of the podu in terms of hectares/acres, c) whereabouts of the places where firewood was collected regularly and occasionally, and, d) number of cattle and location of areas that are often/seldom grazed.

I found that people had to walk further to collect non-timber-forest-products in areas affected by Lantana compared to areas not affected by Lantana. This would imply that people had to spend substantially more time to collect NTFPs if Lantana is present around their settlement. This will obviously reduce the amount of time that they have available for other activities. Even if the estimated area used by the Soligas is an overestimate, there is no reason why the relative overestimate should be different among the different levels of relative Lantana cover.

The positive relationship between the relative intensity of disturbance and the density of Lantana is only indicative of the causal relationship. It cannot be implied that higher disturbance intensity itself causes greater density of Lantana. The absence of regenerating woody plants above a critical density of Lantana demonstrates that no understorey vegetation can become established, once Lantana is sufficiently dense. Neither cattle nor goats eat Lantana, and areas traditionally used for grazing can therefore not be used anymore. Traditionally, villagers would use areas outside the park boundaries for grazing. Grazing on many of these areas have, however, become impossible. Instead, the villagers walk cross the park boundary and walk further and further into the park in search for grazing areas. This increased distance has meant a big increase in the time the local villagers have to use to reach good grazing grounds. It also affects the livelihood of the local tribal people, which have legal permission to live and sustain themselves within the protected area.

Our future research activities will specifically investigate the causes for higher density of Lantana, and the underlying causes for the spread of invasive species.

Figure 1: A general conceptual model of how invasive species may affect conservation of biodiversity and local people's livelihoods.





## PLANT PESTS AS ALIEN INVASIVE SPECIES: SUCCESS AND FAILURE OF EUROPEAN PHYTOSANITARY MEASURES - A GERMAN VIEW -

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**Keywords:** *pine wood nematode, Dutch elm disease, North American oak wilt, New Zealand flatworm*

### *Introduction*

Five different plant pests are described, which are alien to the EU region, have a high invasive potential and threaten ecosystems, habitats and species. The pine wood nematode (*Bursaphelenchus xylophilus*) is an example for partially successful EU phytosanitary measures against alien invasive species. The fungi *Ophiostoma ulmi* and *O. novo-ulmi*, causing the Dutch elm disease, show how essential the damage caused by alien invasive species can be, if phytosanitary measures fail. The fungus *Ceratocystis fagacearum* causes the North-American oak wilt. EU phytosanitary measures against its introduction into Europe which would result in a massive die back of European oak species are effective up to now demonstrating that lessons are learned from the disastrous situation concerning the Dutch elm disease. These four species are plant pests directly affecting plants. The fifth, the New Zealand flatworm *Arthurdendyus triangulatus*, is affecting plants indirectly by reducing the soil's fertility.

### *Description of the alien invasive species and their impact on plants*

#### ***Bursaphelenchus xylophilus***

The pine wood nematode *Bursaphelenchus xylophilus* has been introduced from North-America into Japan and China, causing epidemic wilting and dying of pines. In Japan, one quarter of the pine forest has been destroyed by *B. xylophilus*. The nematode is transmitted naturally over short distances by the longhorn beetle *Monochamus spec.* Long distance spreading is mediated by human activities, e. g. trade with wood or using wood for packing and storage. In Europe, the nematode was recorded for the first time in 1999 in *Pinus pinaster* trees on the peninsula Setubal, Portugal (Mota et al. 1999). The pathway of that introduction is unknown (possibly wood packaging). Most susceptible trees in Europe are *Pinus sylvestris*, *P. pinaster*, and *P. nigra*.

#### ***Ophiostoma ulmi* and *O. novo-ulmi***

The fungus *Ophiostoma ulmi* is causing the Dutch elm disease. It has been introduced from Asia - probably by imported wood - into Holland in the 1920's and then into North-America in the 1930's. Main symptoms of the disease are wilting and a gradually dying of the tree. Only Asian elms are resistant against the fungus. In Europe the fungus is transmitted naturally over short distances by the elm bark beetles *Scolytus scolytus* and *S. multistriatus*. Long distance spreading is mediated by human activities, e. g. trade with elm wood and plants. In the end of the 1960's, a new species of the fungus, *Ophiostoma novo-ulmi*, being much more aggressive, was introduced into Britain by imported elm wood from Canada and spread quickly into Central-Europe, resulting in a die back of nearly all trees of the Genus *Ulmus* there. The origin of this new species is mysterious. Research using DNA finger-printing methods (Bates et al. 1993) showed that the two species are related, but that *O. novo-ulmi* could not have arisen from *O. ulmi* by a simple mutation.

**Ceratocystis fagacearum**

The fungus *Ceratocystis fagacearum* is causing the North American oak wilt, which is most common on red oaks, but causes also serious damage on certain other oaks. Main symptoms are a bronzing or wilting of leaves and leaf dropping. Trees often die within one season. It is considered to be the most serious oak disease in North America. The fungus is transmitted naturally over short distances directly from tree to tree through root grafts and also by insect vectors. Long distance spreading is mediated by human activities, e. g. trade with oak wood and plants. Up to now, it is not introduced into Europe. European oak species are as susceptible to the disease as the American red oaks, a die back comparable to the effects of the Dutch elm disease could be the results of the fungus' introduction.

**Arthurdendyus triangulatus**

The New Zealand flatworm *Arthurdendyus triangulatus* (formerly: *Artioposthia triangulata*) is a ter-restrial planarian preying on earthworms. It may reduce earthworm populations essentially within one year and affects by this indirectly the fertility of soils and thus indirectly the plants. The flatworm has been introduced from New Zealand into Northern Ireland, Scotland and England during the 1960's and into the Republic of Ireland and the Faeroe Islands during the 1990's, possibly by potted plants (Alford 1998). According to its ecological needs, the flatworm could establish in other parts of Europe.

***Implementation of phytosanitary measures, including assessment of effectiveness***

Though existing harmonised European phytosanitary measures failed to prevent the recent introduction of *B. xylophilus* into Europe/Portugal, a spread of it could be prevented up to now. Portugal is obliged by the EC decision 2000/58/EC to take official control measures aiming at eradication of the pine wood nematode and to monitor it at a national level. All EU member states are obliged to conduct official surveys in their countries in 2000. Only 8 samples from the infested area in Portugal out of 5200 taken in all EU-countries contained *B. xylophilus*. Main measures against the introduction of *B. xylophilus* are heat treatment of wood from infested areas and the control of plants. The preferred phytosanitary measure against the Dutch elm disease would have been the prevention of the fungi's introduction, or at least, their eradication at a very early stage of introduction. Lack of experience and of appropriate regulations may be the reasons for this failure. Investigations are in process concerning the control of that disease by molecular biological means and the re-establishment of elms being re-sistant to the disease, but success is questionable. The prevention of an introduction of the North American oak wilt is successful up to now. Phytosanitary measures are specified in the EC Council Directive 2000/29/EC, comprising the prohibition to introduce isolated bark of oaks as well as plants of oak with leaves from non-European countries into EU member states. Wood of oak originating in North American countries has to be bark free, and either squared, heat treated or dried below 20%. Two guidelines on *Arthurdendyus triangulatus* ("Import Requirements"; "Nursery Inspection, Exclusion and Treatment") have recently been accepted by the Council of the European and Mediterranean Plant Protection Organisation, thus demonstrating that also indirect effects on plants may be subject to phytosanitary regulations.

***Conclusions***

Phytosanitary measures and regulations can help to prevent the introduction of alien invasive species directly or indirectly injurious to plants or mitigate their impact. All five alien invasive species described here have or may have serious impacts on natural or semi-natural ecosystems. Phytosanitary measures are a useful tool to protect ecosystems against the damage which could be caused by those species.

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## ALIEN INVASIVE PLANTS THREATENING THE AGRO-ECOSYSTEMS OF SRI LANKA

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**Keywords:** *Alien invasive plants, agro-ecosystems, management*

### **Introduction**

Over the past centuries, the ever-increasing human population has contributed to the over-exploitation of animals and plants, as well as to the degradation or modification of natural habitats. Besides these two anti-biodiversity anthropogenic factors, there is yet another danger to our biological diversity today; the growing threat of alien invasive biota. It has been well documented that alien invasive species (AIS) have resulted in massive and rapid losses of biodiversity, especially in island communities (Clout 1995).

The importance of understanding the impact of alien invasive plants in Sri Lanka, a small island in the Indian Ocean, has been felt recently. Several alien plants found in Sri Lanka, have been reported to spread at an alarming rate threatening the 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 (Wijesundera 1999). This paper gives an account of some alien invasive plants reported in Sri Lanka affecting the agro-ecosystems and the efforts taken to mitigate the problems.

### ***Alien Invasive Plants in Agro-ecosystems of Sri Lanka and Their Management***

#### **Eichhornia crassipes (Water hyacinth)**

Water hyacinth has been introduced to Sri Lanka due to its horticultural value. However, two years after its introduction to the country, a Water Hyacinth Ordinance was enacted in 1909 to tackle the problems of this species. However, despite this effort, *E. crassipes* is still a major aquatic weed in Sri Lanka choking water bodies, and affecting the maintenance of irrigation schemes. Biological control techniques to manage water hyacinth populations were introduced to Sri Lanka in 1980's, however, *Neochetina eichhorniae* and *N. bruchi* have not performed to the expected levels. Thus, mechanical removal has been practiced to clean water bodies infested with this aquatic weed, resulting in its spread due to contamination of the machinery used.

#### **Salvinia molesta (Salvinia)**

*Salvinia*, introduced to Sri Lanka in late 1930's for scientific interests, is a major aquatic weed in Sri Lanka choking the irrigation canals and water bodies, and also invading rice fields in the north-western province of the island nation. Although there is no accurate information on its degree of infestation, in 1988, about 8000 ha of rice fields were reported to have infested with rice fields (Amarasinghe and Ekneligoda, 1997). Due to the detrimental effects of this aquatic fern to the agricultural ecosystems of Sri Lanka, *Salvinia molesta* came under the strict control of the plant protection ordinance in Sri Lanka. Although the biological control with *Cyrtobagus salviniae* is successful in several areas in Sri Lanka, the attempt has failed in cooler climates and areas with low water levels and high environmental temperature (Amarasinghe and Ekneligoda, 1997).



**Mimosa pigra (Giant sensitive plant)**

Giant sensitive plant has been identified in Sri Lanka growing luxuriantly in the riverbanks of Mahaweli, which is a major source of irrigation water that supports the agricultural crops in Sri Lanka, and also in other areas in the central province spreading at an alarming rate (Amarasinghe and Marambe, 1997). Although the pathway of entry of this plant into the country is not well understood, it is widely believed that this alien invasive 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 via irrigation water, machinery, river sand used for construction purposes, and lopping with mature pods as a result of the use of stem of the plant as a firewood by people (Marambe et al., 2000).

**Alternanthera philoxeroides (Alligator weed)**

Alligator weed was an accidental introduction to Sri Lanka, which has spread rapidly due to human intervention. The weed, easily misidentified to a commonly cultivated leafy vegetable *Alternanthera sessilis*, has invaded more than 200 ha of land in the southern province of Sri Lanka, through direct human intervention. The state Department of Agriculture has now taken measures to eradicate the plant from cultivated land with the assistance of the farming community.

**Parthenium hysterophorus (Congress weed)**

Congress weed is the latest recorded alien invasive plant in Sri Lanka. The weed has occupied about 150 ha of fallow agricultural land in the upcountry area and some parts of Kandy district of the central province, and Vaunia district of the northern province. The available information indicates that the seeds of *P. hysterophorus* has been introduced to Sri Lanka together with onion and chilli seeds imported from India. This is a classic example of the impact of open trade policies and poor quarantine measures on spread of alien species.

**Anredera cordifolia**

This is a perennial vine, identified as an invasive weed in tea plantations of Sri Lanka. *A. cordifolia* has been reported to be an introduction to tea plantations as the tubers of this plant are edible (S.L. Ranamukaarachchi, personal communication). All the control measures adopted have failed due to that the weed use the tea bushes as the support to grow and produces large number of aerial bulbils and tubers.

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## YELLOW NUTSEDGE (CYPERUS ESCULENTUS L) IN THE NETHERLANDS; INVASION, DETECTION, MEASURES AND RESULTS

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**Keywords:** *Cyperus esculentus*, invasion, measures, results

### ***Biology and significance***

*Cyperus esculentus*, or yellow nutsedge is belonging to the worlds worst weeds as described by Bendixen and Nandihally 1987. Yellow nutsedge is a monocotyledonous perennial weed forming large rhizomatous mats during the growing season and surviving the off-season with bulbs. Bulblet production may be very high (Stoller and Sweet 1987; van Groenendael en Habekotte 1988.) The plant thrives best under moist subtropical conditions and irrigation boosts its population growth. Yellow nutsedge is sensitive to shade and cold, though the bulblets survive frost quite well. Populations are often promoted by the chemical control of other weeds, as yellow nutsedge is tolerant to most selective herbicides according to Perreira et al, 1987. The species flowers in profusion but seed set is rare and seedlings have never been found in Dutch fields. Germination is extremely poor under laboratory conditions. A number of varieties differing in their biological characteristics exists. ( Borg et al . 1998). Yellow nutsedge is in the Netherlands a weed of arable land used for open summer crops. Outside agriculture it is of no significance. Damage in agriculture is through competition decreasing yield and quality of produce. The rhizomatous mats may hinder or even prevent mechanised harvesting. Control is by directed cultural and chemical means and therefore costly. Some horticultural crop rotations cannot be sustained under dense infestations.

### ***Invasion***

Yellow nutsedge was accidentally introduced in the Netherlands through the import from the USA of gladiolus corms for propagation around 1980. Invasion took place through planting of contaminated propagation stocks to ever new fields, necessary because of dry rot prevention in gladiolus crops. Spreading by other propagation materials such as nursery stock has been documented. Infested soil and machinery are also known to play a role. Practically all spread is by man. The area increase was estimated at about 10% per year in the early eighties which was quickly brought to a standstill after introduction and enforcement of legal measures in the mid-eighties.

### ***Detection***

*Cyperus esculentus* can be easily identified because of its typical bulblets which have no equivalent in the Netherlands After the first case in 1981 a regional scan produced over 40 cases and an impression of the pattern of invasion. Intensive visual inspection of standing crops in the period from July to end of September has been the method used. Fields were selected by cropping history and regional indications. The method is time consuming and very reliable.

### ***Measures***

The measures taken were legal provisions aimed at prevention of spread and induction of control by farmers (Naber and Rotteveel 1986), training of Plant Protection Service personnel and others, education and awareness oriented activities within the farming communities. In 1991 the government decided that nutsedge should no longer be regulated by official authorities. After two years of vacuum (and population increase as expected) the farmers organisations continued alone with the same set of restrictions on infested fields. Since the area of infestation remains at < 1000 ha the total economic impact is small, though high on heavily infested farms. (Wilms and Smeets,1984). Responsibility for decisions and actions was largely with the Plant Protection Service in the period from 1981 to 1991. Afterwards regional farmers organisations took responsibility, but had most of the work done by the Plant Protection Service.

In 1981 government decided to declare nutsedge a noxious organism which was used to implement both measures on the border and on the propagation materials sold off-farm. In order to implement and maintain measures infested fields were tracked and officially declared infested. The farmers organisation issued a decree demanding the cleaning of all equipment used on infested fields. Measures turned out to be difficult to apply in many crops and inspection was difficult. Therefore it was decided that the growing of all rootcrops would be banned on infested land. A ban would be lifted if inspection would not indicate the presence of any nutsedge during three consecutive years. The measures were backed by the work of a national working group on nutsedge which worked on control and biology in the Dutch context. A validated population model was among the results (van Groenendael and Habekotte, 1988) A leaflet was produced and much attention was given to the problem in the press.

### **Results**

The action was successful during the years 1986-1991 when the ban on rootcrop farming was in place, field inspection was intense and infestations declined dramatically in severity and in number (Rotteveel, 1993). In the years 1992 and 1993 a legal vacuum existed and some infestations increased and spread again. In most cases farmers continued control with an eradication aim. When the farmers organisations gradually took over after 1994 a gradual decline in nutsedge populations was noticed. Containment has been largely reached because the rate of dispersal is now very low. Eradication has been obtained on ca 30% of the infested fields, on practically all other fields infestations are at very low levels. (Rotteveel 1993).

### **Conclusion**

*Cyperus esculentus* is an alien invasive weed with a high potential for damage in the Netherlands and which is currently being contained successfully. Successful action is dependent on continuing political and societal support providing the means for action.

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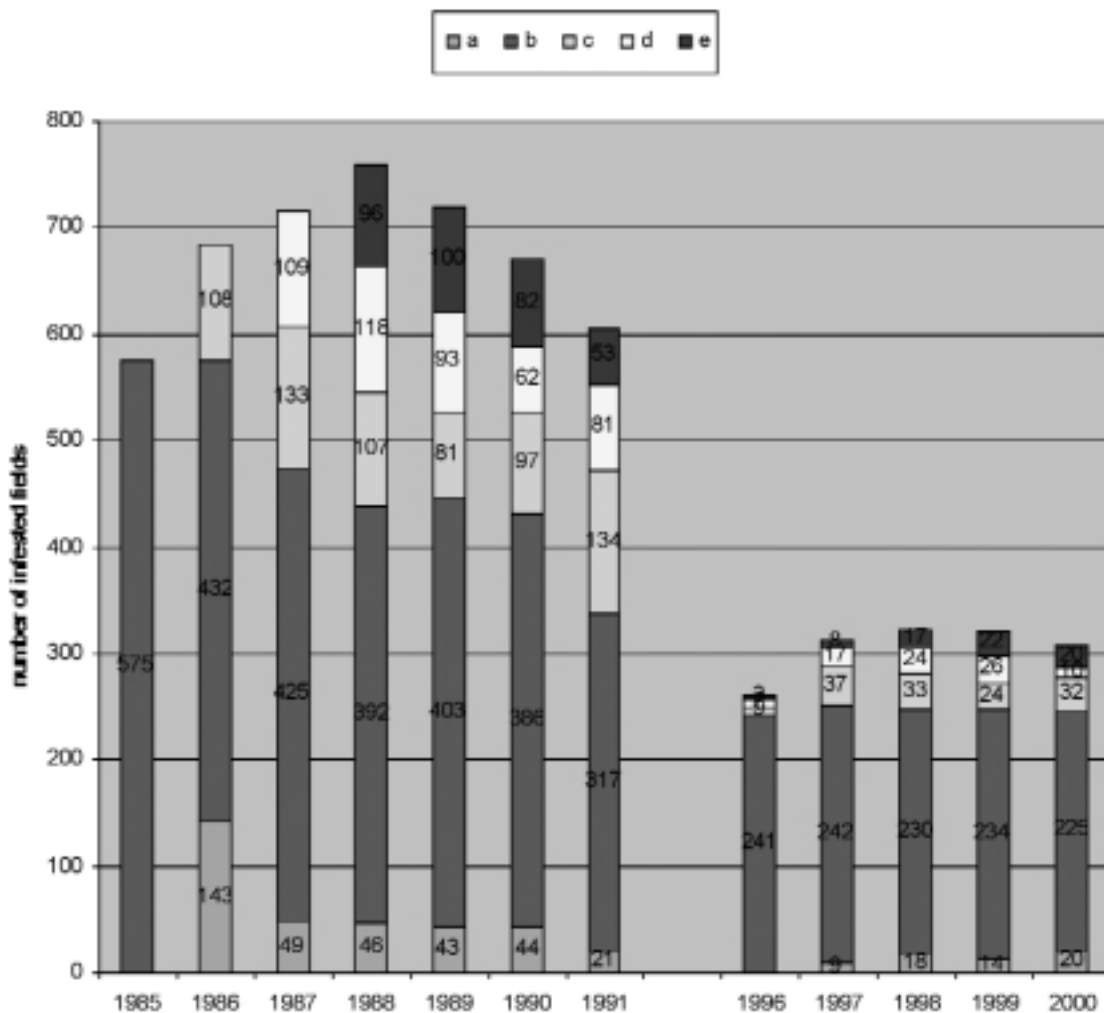
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## TERMITES OF ECONOMIC, SOCIAL AND ENVIRONMENTAL IMPORTANCE IN URUGUAY

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**Keywords:** *Isoptera, damages, environment, Uruguay*

The territory of Uruguay extends between parallels 30° and 35° South, and meridians 53° and 58° West. It lies entirely within the temperate zone. Is mostly rolling country, without great elevations (maximum altitudes around 600 m) and does not have any marked variations of climate in the different parts of the country. It limits at the N. and E. with the Federal Republic of Brazil, and to the W. with the Argentine Republic. Its SW. coast is on the Rio de la Plata and at the SE. lies the Atlantic Ocean.

Uruguay subscribed the Accord on Biological Diversity on August 27, 1993 (Law 16408), thus agreeing to follow the terms of that document. Accordingly, a "National strategy for the conservation and rational use of the biological diversity in Uruguay" was issued in December 1999. The study of biological diversity in land was included, and as a part of it, that of the insect fauna. Within the latter, the Order Isoptera has a particular importance. It includes the Termites or White Ants. They are social insects, many of its species building nests which are often large and intricate, that they use as a permanent abode. More than 2000 species are known in the world. Their societies are complex, being formed by several different castes, each one fulfilling a particular social function. Their communities are an example of complex social organization and activity (Grassé, 1982, 1984, 1986). All the species of termites without exception, have some sort of economic importance, though for many of them its meaning and importance with relation to human activity is not yet well known. Anyway, what we know of the ones that have been well studied, reveals in many cases that they are very destructive. This characteristic, together with their general presence, gives them a considerable weight in the economy of men and also a true socio-economic interest. It is also known that many species are beneficial, because they use and transform dead and decaying vegetable matter, making it available again to the general economy of Nature.

In later years another possible economical interest of the termites has began to be investigated. It is not related to their destructive aspects but their possible use as human food. Studies made in different parts of the world revealed that termites are a potential source of proteins and fat of high nutritional value. Some of its species, besides, have a high content of iron, and it has been indicated that they could make an interesting complement to the food in countries like the Philippine Islands, where some types of anemia are endemic in poor sections of the population. In Uruguay, termites are frequently used in rural areas as a complement to the food of poultry. This is especially the case for termites that build mound-like nests (*Nasutitermes fulviceps* and *Termes saltans*). The observations of how the chimpanzees use a straw or twig to get termites = out of their nests for their use as food are well-known.

In Uruguay, in recent times, our attention has been directed to certain species which are destructive, in one case of timber used in construction, in another of wood of living fruit trees and grapevine. The first one is certainly exotic and has been involuntarily imported, the second seems to be autochthonous. Of special importance is the one that attacks timber. Its control includes special techniques of construction, and often treatment of building areas and timber with insecticides. Laws and regulations related to the presence of termites and prevention of damages have been issued. Information on ways to prevent and avoid termite damage has been given to the general public in the affected areas. Here in South America, there is much information on the composition of the termite fauna. Of relevant importance are the pioneer studies of the Italian entomologist F. Silvestri (1903), that have been the base of all the following studies on the taxonomy of these insects. Several species have been signalled or described for Uruguay.

Some of them, such as *Nasutitermes fulviceps*, build mound-shaped nests, with an important hypogeic area besides the epigeic one (Tálice et al., 1969). *Termes saltans* builds a nest with only a small hypogeic construction (Aber and Laffitte, 1984). Others, such as *Reticulitermes lucifugus* build entirely subterranean nests (Aber & Baillod, 1991). *Rugitermes* sp., now under study, seems to live entirely in galleries inside tree trunks (Aber, 1999). *Reticulitermes lucifugus* (Isoptera, Rhinotermitidae) is an important pest species because it destroys sound wood used in buildings. It was detected in the sixties, and to the present times its area of distribution has steadily increased, and so has its economic importance. Damage in the buildings occur mainly in socles, floors, door door frames, window frames, etc. Homes, public buildings and shops have been damaged. These termites are active destructors of sound wood and of any article containing cellulose. Hence their activities are especially destructive in libraries. Any kind of material that includes fibres of plant origin is subject to attack. Dry wood of eucalyptus and pine have been attacked here in Uruguay. In infested brick buildings they make galleries on walls and ceilings by which they reach and attack new pieces of wood. To build these galleries, termites of the worker caste begin by marking a track with the secretion of their sternal gland. Then they begin the construction of a roofed gallery, starting at the lateral edges of the track and gradually making the walls and roof until they complete the arch. The internal surface of these galleries is polished and homogeneous, the earthen granules of which it is built being strongly cemented and compacted. The outer surface, on the contrary, is rough. These galleries are usually straight but they may have many branchings. When kept in the laboratory these termites build sometimes vertical tubes from one piece of wood to another placed below it (Aber, 1992, 1993). In infested buildings they frequently use the tubes of the electric wires as ways for their dispersion. Studies of the ecosystem have been made as a possible mean to predict their future dispersal (Aber & Beltrami, 2000). The origin of this species in Uruguay is not known for certain. The evidence indicates that it is an exotic species accidentally introduced, probably in wood crates. Our finding of this highly destructive species has made us aware of the problem of how to prevent new importations of this or similar pest species. Also, we have tried to devise the means to stop or restrict the spreading of these insects within the country, and also for avoiding their propagation to neighboring countries. We are working also to find the best means to control this species, avoiding as far as possible the contamination of the environment with insecticides, especially if they are not biodegradable or highly toxic. Treatment of the timber to be used for building purposes has been recommended.

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House infested by *Reticulitermes lucifugus*



Tree damaged by *R. lucifugus*

Books damaged

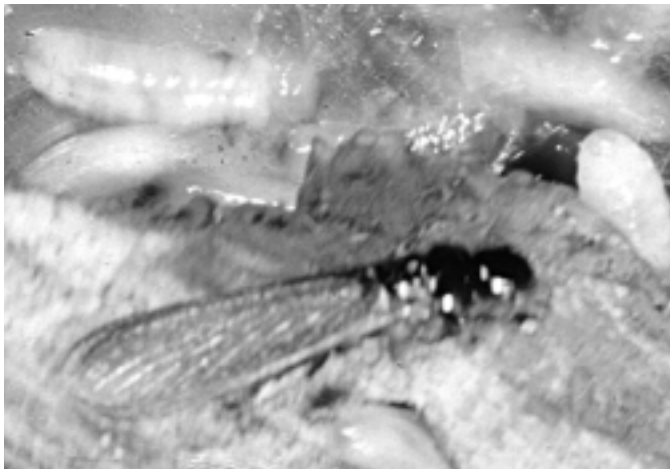




Soldier Termite



Wood damaged by *Reticulitermes lucifugus*



Winged form of *Rugitermes* sp.



Log with population of *Rugitermes* sp.



Vineyard with *Rugitermes* sp.

## PREDICTING THE EFFECTS OF CACTOBLASTIS CACTORUM BERG ON THE PLATYOPUNTIA OF MEXICO: A MODEL ON THE ROUTE OF INVASION

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**Keywords:** *bioclimatic modelling biological invasions, Cactoblastis cactorum, Mexico, Opuntia.*

### Introduction

Biological control is considered an appropriate method of pest control and is still regarded as an important means of eliminating species that threaten biological diversity and affect agricultural produce worldwide (Strong and Pemberton, 2000). However, the main concern in the introduction of agents for biological control is host specificity (Simberloff and Stiling, 1998), especially because several "runaway" biological control agents have been recorded (Pemberton, 2000). Since its introduction to Australia in the 1920's, *Cactoblastis cactorum* Berg has been regarded as one of the best agents for the biological control of prickly pears (Dodd, 1940). *C. cactorum* has been used as an aggressive biological control on several species of *Opuntia* (Julien 1992) since its introduction into Australia and other parts of the world. *C. cactorum* has now been found in the Florida keys, probably arriving there by direct transport of infected individuals (Pemberton, 1995) or by natural dispersion (Stiling and Simberloff, 2000), causing impacts on the endangered *O. spinosissima* (Martyn) Miller, and has the potential of damaging two more species of *Opuntia* found in Florida. In Mexico, the danger posed to natural populations of *Opuntia* is still unknown, however, the experience in Florida and elsewhere would make us expect a serious threat to Mexican species. The purpose of this investigation is to model the possible routes and predict the most heavily damaged areas of Mexico after an invasion by the cactus moth *C. cactorum* that has already reached continental North America and is likely to migrate to the native *Opuntia*-rich areas.

### Methods

In order to model invasion, we used bioclimatic modeling (FloraMap ver. 1.0 Jones and Gladkov, 1999) to look for North American areas of climatic similarity to original *C. cactorum* localities. FloraMap searches for cells in the grid that are "similar" to those where a species has been observed, by using Principal Component Analysis (PCA) on the climatic variables measured over the data points. The PCA analysis generates a probability distribution of similarity which is displayed on a map. Regions in Mexico with a high incidence of *Opuntia* (*Platyopuntia*) species were obtained using GARP (Stockwell and Noble, 1991, Stockwell and Peters, 1999) that uses a set of climatic and physiographic coverages (annual mean temperature, annual precipitation, elevation and potential radiation) to predict species distributions. Data on the occurrence of *Opuntia* was determined using the databases in CONABIO, supplemented with data from several other herbaria (MEXU, ENCB, SD), for a total of 56 species and 1124 specimens. The GARP algorithm yielded a geographical cover of areas of high similarity to those where the species has been observed, that were corrected by subtracting those areas where the presence of the species had never been recorded. The surfaces for all species were then overlaid to produce incidence maps for groups of *Opuntia* species with a different risk of being attacked by the moth. We used three criteria to identify the risk of attack by *C. cactorum*. Correlations generated a matrix of 108,546 data points that contained the probability of attack by *C. cactorum* as well as species richness for each spatial data point.

### Results

Of the 52 species of *Opuntia* that were considered in this study, close to 10% were known to be attacked by *C. cactorum* (criteria 1; Fig. 1A), and those potentially capable of being attacked (same taxonomic series) consisted of close to 20% of all Mexican species (criteria 2; Fig 1B). The 1124 reference points used to determine the distribution of species of *Opuntia* with GARP in Mexico (criteria 3; Fig. 1C) suggested the largest concentration in areas that are located south of latitude 21 with some sparse locations in the Sonoran and Chihuahuan deserts. These areas are predicted to have the conditions necessary for *C. cactorum* invasion comprising 49.11% of areas that overlap between distributions. The probability of occurrence of *C. cactorum* comprises 44.23% of total area with the areas most likely to be invaded by *C. cactorum* concentrated in the northeastern part of the country limiting its distribution to the eastern portion of central and northern Mexico. Taking into account the most critical species (criteria 1), 23.75% of total area overlapped both distributions with the highest risk concentrated in the northeastern portion of Mexico having the high *Opuntia* species diversity as well as appropriate environmental conditions for *C. cactorum*. The areas with lower risks are found in the central portion of Mexico and only had 13.37% overlap between the two distributions.

### Discussion

The distribution of the genus *Opuntia* in Mexico favors the expansion of *C. cactorum* from the North to the Southern parts of Mexico. The risk to the *Opuntia*-rich areas of Mexico seems to be comparatively low, however these preliminary predictions are probably an underestimate of the potential damage. The tolerance of *C. cactorum* to different environments is unknown and its adaptability to different habitats could alter the probabilities of the potential distribution of *C. cactorum* in Mexico. Research regarding the choice of *C. cactorum* on a wide range of *Opuntia* species is needed in order to increase the capacity of predicting the route of invasion and the possible economic and ecological costs. The route of invasion can be facilitated by the abundance and large distributional range of *O. stricta*, *O. lindheimeri* and *O. littoralis*, species known to be attacked by *C. cactorum* in Australia. At least 60 native species of *Opuntia* could be damaged in the US including 12 rare species and the impact on species found in Mexico can be much larger. More accurate and predictive results could be obtained with larger data sets for some species. Bioclimatic modeling can be a powerful tool to determine species invasions and pinpoint areas of susceptibility.

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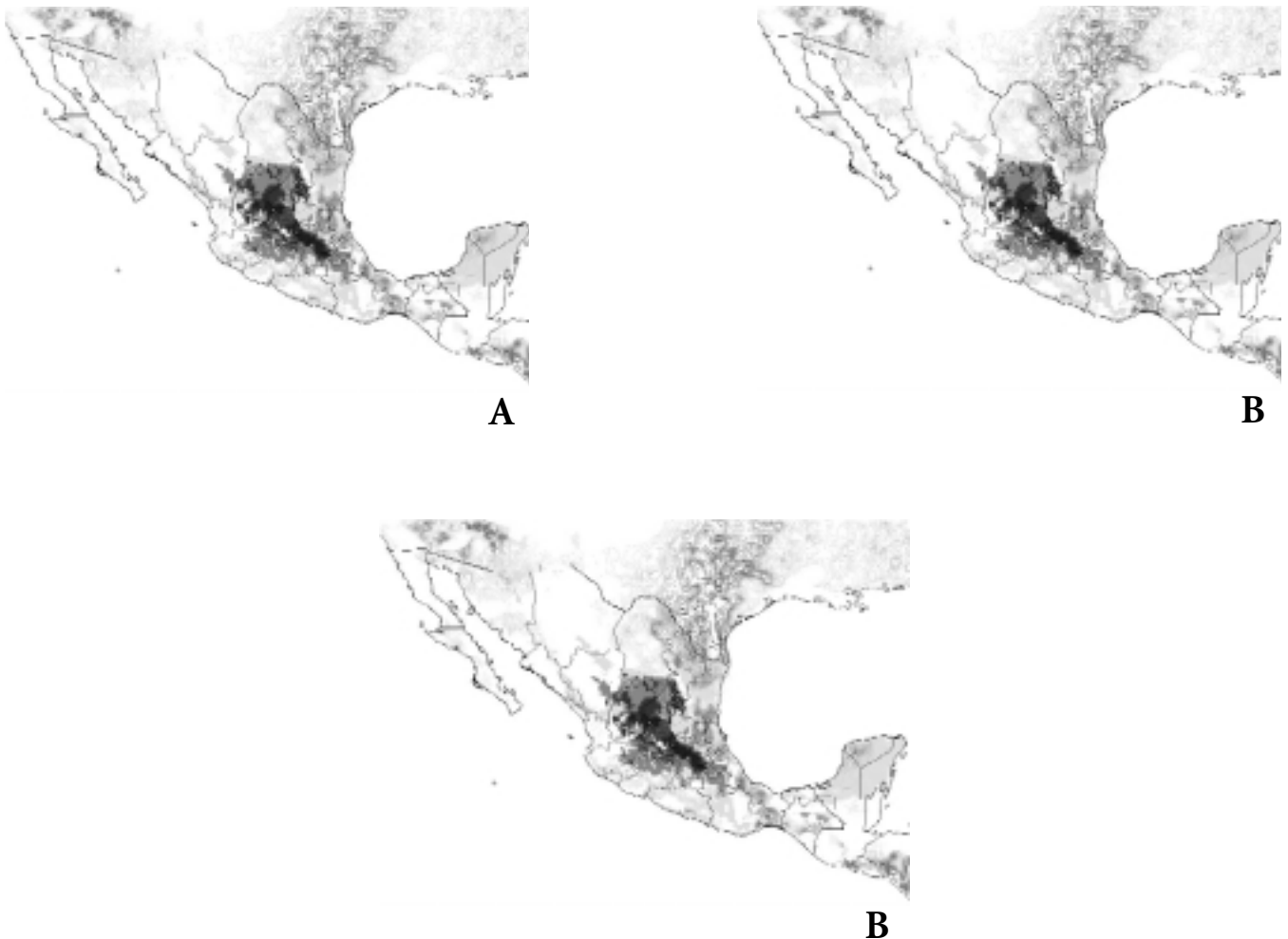
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**Figure 1. Regions of high similarity to *Cactoblastis cactorum* "hotspots" in Mexico, calculated using FloraMap on climatic variables (red contours) and regions *Opuntia* species richness calculated superimposing individual GARP areas (area in blue). A) Species known to attacked by *C. cactorum* B) species closely related to those known to be susceptible to attack and C) all species of *Opuntia*.**



## INVASIVE PLANTS IN MIXED-GRASS PRAIRIE

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***Keywords: biological control, natural areas, ecological effects of infestation, nutrient cycling***

The purpose of this poster is to present an overview of research on invasive plants in the northern mixed-grass prairie currently being conducted by scientists and graduate students at Northern Prairie Wildlife Research Center. Our primary goals are (1) to evaluate existing methods of control of invasive plants and to use ecological principles in developing ways to improve upon them, and (2) to assess the ecological effects of both invasive infestations and the methods used to control them. Our overarching objectives are to explicitly consider the interactions among control methods, plant invasions, and the biotic and abiotic variance inherent to mixed-grass prairies, and the effect these interactions have on native plant communities and ecosystem properties.

### ***Control of invasive plants***

Throughout the Dakotas, control of leafy spurge (*Euphorbia esula*) and Canada thistle (*Cirsium arvense*) has relied to a large extent on introduction of biological control insects and application of herbicides. Evaluation of these techniques has been haphazard. Work ongoing at Theodore Roosevelt National Park, North Dakota, where an active herbicide program and well-documented releases of flea beetles (*Aphthona* spp.) have been in place for a decade, centers on comparing the fidelity of different species of flea beetles to their release sites in five vegetation types, comparing the effect of biological control on spurge infestations in five vegetation types, and comparing the efficacy of biological control and herbicide application in a vegetation type where both are used.

Insects introduced for biological control of Canada thistle have not, in general, provided acceptable levels of control. Our work at Lake Andes and Lacreek National Wildlife Refuges in South Dakota endeavors to augment biological control with experimental manipulations aimed at shifting the competitive balance away from thistle. By adding carbon to the system, thus tying up nitrogen in microbial biomass, and adding native grasses known to compete well for nitrogen, we hope to not only see a decrease in thistle abundance, but an enhancement of wildlife habitat. Similar studies on leafy spurge at Arrowwood and Tewaukon refuges in North Dakota, where biological control insects have proven more effective, will suggest the breadth of applicability of these techniques.

### ***Ecological effects***

Ultimately, the goal of weed control is to reestablish a more desirable plant community. Often, weeds themselves, or the techniques used to control them, alter ecosystem processes in such a way that reinvasion by weedy species is likely. Using field and microcosm studies at Theodore Roosevelt National Park, we seek to quantify the role of leafy spurge, herbicide, and flea beetles, in changes in nitrogen cycling that will influence the fate of these sites as spurge declines.

Invasive plants may do more than simply compete with natives for space, water, or nutrition. Copious pollen and nectar produced by extensive infestations of leafy spurge substantially change the resource landscape for pollinating insects. The effect on native flowering plants that coexist with leafy spurge may be a change in pollinator visitation rates (up or down) or increased incidence of non-conspecific pollen being introduced to stigmas. A new study at Theodore Roosevelt National Park investigates effects of leafy spurge on the pollinator community, visitation rates to native plants, proportion of non-conspecific pollen deposited on native plant stigmas, and seed set of native plants.

*Future directions*

The interplay among ecosystem-level effects of invasive plants, the effects of control, and the likelihood of reestablishment of native vegetation are important areas of research. Our current work lays a foundation, but merely scratches the surface. Many invasive plants, such as yellow sweetclover (*Melilotus officinalis*), have received little attention because they have value to the agricultural community. Nonetheless, nitrogen-fixers such as sweetclover, which in some years blanket the badlands with an extensive canopy and persistent litter, have the potential to alter successional trajectories on poorly developed badlands soils, as well as to contribute to further invasions by weedy species that could not otherwise gain a foothold in nitrogen-limited prairies.

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## INVASIVE ALIEN PLANTS IN INDIA: DEVELOPING SUSTAINABLE MANAGEMENT STRATEGIES

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**Keywords:** *Invasive alien plants; India; Management strategies*

### *Introduction*

Some of the World's worst invasive alien plants have been present in India for over a century. Prominent amongst these are *Chromolaena odorata* (= *Eupatorium odoratum*) (Asteraceae) and *Lantana camara* (Verbenaceae). Both of these woody, perennial weeds originate from the Neotropical region and seem to have been introduced into India through the Calcutta Botanical Garden during the last century (Thakur et al., 1992; Muniappan & Viraktamath, 1993). Since then, other Neotropical plants have established in the country and become highly invasive. Examples include *Mikania micrantha* (Asteraceae), introduced into Asia as a cover crop during the Second World War, and *Parthenium hysterophorus* (Asteraceae), accidentally introduced in the 1950s. Most recently, *Mimosa invisa* has rapidly expanded its range in the Western Ghats, which is noted for its unique flora and fauna (Kerala Forest Research Institute, unpublished).

The geography of invasion into India by particular species has largely been determined by climate. However, all of these invasive plants favour disturbed habitats without dense shade, and thus commonly invade and form dense thickets in natural forest areas and other natural habitats that have been disturbed through exploitation. They also invade forest and crop plantations, land cleared for agriculture, grazing grounds, open wastelands, roadsides and railway tracks (Thakur et al., 1992; Doddamani et al., 1998). Species like *C. odorata* may contribute to soil stabilization and moisture retention in exploited natural forest and waste land. Nonetheless, in forest ecosystems in northern India invaded by *L. camara*, soil is frequently nutrient- (particularly N-) poor and the plant can pose a major fire hazard in the dry season.

### *Previous Interventions*

Methods of control have been researched and attempted on a local basis to curb the spread of invasive alien plants and reduce their abundance, but none has resulted in any substantial impact. Herbicides have been tried on occasion, but they are frequently costly and afford only temporary relief because surviving vegetative shoots and seeds lead to rapid reinfestation. Herbicides may be appropriate on a spot-application basis and in combination with other techniques, but are inappropriate for wide-scale use owing to environmental concerns. Attempts made to clear invasives from new plantation areas and gardens by hand cutting or burning have failed because the plants quickly re-invade owing to their large seed banks in the soil. Biological control, using native and exotic insect agents, has been attempted against some of the invaders over the last century. Many insects have been recorded feeding on some invasive weeds in India, but most are highly polyphagous and have little impact. Introductions of some host specific exotic insect agents have been made against *C. odorata* and *L. camara* but only a few of the species have established. Some have had an impact on local scale, but this has not been followed through, nor has the opportunity to introduce further exotic agents been pursued.



### *Developing Sustainable Solutions*

It is clear that invasive alien plant problems are complex. In most instances, plants are invasive across a range of habitat types – forests, plantations and agricultural land – and there has been a general lack of involvement of communities in tackling the problems. Together these factors have led to previous efforts, which focused on a single component solution for control, achieving only partial success at a local scale or failing altogether.

Now, some new initiatives in India may start to turn the tide against the invading plants. In the Himalayan and the Western Ghats regions of the country, ecologists from the Jawaharal Nehru University have been leading some promising projects which are developing landscape management plans with local communities. The aim has been to create effective natural resource management strategies to enhance biodiversity in the landscape, in order to keep biological invasions in check. Here it has been important to integrate the ecological with the social dimensions of the problem of landscape management (Ramakrishnan et al., 1996). Ramakrishnan and his co-workers have identified the close parallelism between ecologically significant keystone species and the socially/culturally/religiously valued keystone species. An approach based upon this connection enables local communities to identify themselves with a value system that they are able to understand and appreciate, and thence participate in a rehabilitation activity that could check biological invasion. *Quercus* spp. (oak) in the Central Himalayan region, Nepalese alder (*Alnus nepalense*) in north-eastern hill region, and *Prosopis cineraria* in the arid Rajasthan region represent such keystone species with which communities are able to relate. Further, such an ecological knowledge base operating at a process level has been linked with traditional technologies such as rain water harvesting systems, for triggering/accelerating the rehabilitation process.

These community based approaches can best be complemented with technologies such as biological control through the introduction of exotic agents, which can provide a long term sustainable component to an overall management plan. Recently, the Kerala Forest Research Institute, in collaboration with CABI Bioscience have been researching the use of host specific fungal pathogens for the control of *M. micrantha* in the moist forest zones of south west and northeastern India. Two highly pathogenic fungi have been identified from the Neotropics and screening studies have demonstrated that they are completely specific to the target plant.

The importance of developing a national strategy to support initiatives for the management of invasive alien plants and other invasive species was expressed at a national conference on invasive species, held at the M S Swaminathan Research Foundation (MSSRF), in Chennai, in December 2000; the conference was organized by MSSRF, the Ministry of Environment and Forests, the Ministry of Agriculture, and CAB International. The conference endorsed a number of recommendations aimed at strengthening prevention and management schemes at the local community, state, national and international levels of government.

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## INVASIVE ALIEN PLANT SPECIES THREATEN NATIVE PLANTS AND BUTTERFLIES IN ROCKY MOUNTAIN NATIONAL PARK, COLORADO, USA

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### *Abstract*

In a landscape-scale assessment of species diversity patterns in Rocky Mountain National Park, Colorado, USA, areas richest in both butterfly and vascular plant species overlapped with areas of alien plant species invasion. Patterns of butterfly species richness in a 754 hectare study area were positively correlated with total vascular plant species richness ( $r=0.69$ ;  $p<0.001$ ), as well as native plant species richness ( $r=0.64$ ;  $p<0.001$ ) and cover ( $r=0.68$ ,  $p < 0.001$ ). However, butterfly species richness was also positively correlated with both exotic plant species richness ( $r=0.70$ ;  $p<0.001$ ), and cover ( $r=0.70$ ,  $p<0.001$ ). This may be related to the observation that many butterflies and other nectar feeders are attracted to the flowers of certain alien invasive plant species such as musk thistle, *Carduus nutans* Linnaeus, and Canada thistle, *Cirsium arvense* Linnaeus. Coincident patterns in species richness could simply reflect the distribution of resources, but we are concerned that both native plants and butterflies could be negatively impacted by alien plant species invasion in the richest habitats.

### *Methods*

For the correlation analyses we measured butterfly species richness as well as vascular plant species richness and areal cover in the 754 hectare Beaver Meadows study area in Rocky Mountain National Park, Colorado, USA. The design emphasized stratified-random sampling to include replication in common as well as rare and unique vegetation types (Stohlgren et al., 1997). Nested multiple-scale butterfly plots (Simonson, 1998) were overlaid directly on the 20m x 50m modified-Whittaker vegetation plots (Stohlgren et al., 1995). Timed, systematic butterfly surveys were conducted at the twenty-four 0.1 ha plots four times during June, July, and August 1996 (Simonson et al., 2001). Photographs and detailed observations were used to document flower visitation in the study area and surrounding landscapes.

### *Results*

Butterfly species richness in the study area was best explained by the number of exotic plant species and their cover. Patterns of butterfly species richness were positively correlated with total vascular plant species richness ( $r=0.69$ ;  $p<0.001$ ), as well as native plant species richness ( $r=0.64$ ;  $p<0.001$ ) and cover ( $r=0.68$ ,  $p < 0.001$ ). However, butterfly species richness was also positively correlated with both exotic plant species richness ( $r=0.70$ ;  $p<0.001$ ) and cover ( $r=0.70$ ,  $p<0.001$ ).

We observed high concentrations of insects (principally butterflies and bees) at the flowers of certain invasive alien plant species. While successful invasive plants are often wind pollinated, such as *Bromus tectorum* (cheatgrass), a variety of alien plant species produce showy, fragrant flowers that have been noted as attractive to generalist nectar feeders. Principle examples from our study area include *Cirsium arvense* (Canada thistle), and *Carduus nutans* (musk thistle).

### *Management Implications*

If many flower visitors favor alien invasive species, native plant and pollinator interactions could be disrupted. Native plant species may receive inadequate pollination, resulting in reduced fruit and seed set. This could in turn reduce native plant establishment and enhance alien plant invasion success.

While adult butterflies will often feed from a wide variety of nectar-producing plants, butterfly larvae often feed on only a few species of native plants. Loss of native plants could mean less opportunity for the butterflies to reproduce. The availability of suitable host plants is often of critical importance for the persistence of rare and threatened butterfly species.

Invasive species management actions must be done carefully to avoid damaging native plant species and co-occurring animals. To help resource managers make decisions concerning alien plant species invasions in the richest habitats, further research is needed to determine potential effects on neighboring native plant species, as well as butterflies and other native pollinators.

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## MODELING SPECIES INVASIONS: NEW METHODS AND NEW DATA FROM BIODIVERSITY

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***Keywords: Nonindigenous species, ecological models, invasive species***

Human activities have increased the wholesale movement, either accidental or deliberate, of many species of animals and plants from one region of the planet to another. Invading species have often been able to establish populations in the new regions, many spreading successfully over large areas or achieving high abundances. Unfortunately, many of these invasive species have severely affected existing natural systems by displacing or competing with native species and altering native habitats, or by damaging agroecosystems and other human resources.

Existing strategies for combating invasive species are reactive; that is, strategies for combating an invasive species are developed only after an invasion has occurred and collateral damage has been detected. Utilizing these approaches always puts decision makers and environmental managers in a catch-up mode. A wiser approach, both biologically and economically, calls for a proactive strategy that anticipates species invasions before they occur or, at the very least, predicts which geographic areas are at maximum risk for the successful incursion and spread of potential invasive species.

A model of the ecological niche of a species can be created via comparisons between known occurrence points and ecological characteristics of the landscape. Data for these models are available for almost all species—occurrence points can be garnered from scientific specimens or observations, and electronic maps are available for many important ecological dimensions as GIS coverages. The Genetic Algorithm for Rule-set Prediction (GARP), an artificial-intelligence application, offers the most robust, and is the best tested algorithm for developing such models. Using GARP, the geographic locations of ecological features (both defined in latitude-longitude space) are translated into a model of suitable and unsuitable habitat in ecological dimensions. This ecological model can then be projected onto landscapes to identify areas that are suitable for that species' populations.

The existence of an ecological niche model makes possible projection of the species' distribution onto any landscape, including invaded ranges, but also including other scenarios of change, such as climate change. These maps should allow decision makers and environmental managers to make better decisions about invasive species.



## MANAGING BIODIVERSITY IMPACTS OF MULTIPLE ALIEN SPECIES: ROTOITI NATURE RECOVERY PROJECT, NEW ZEALAND

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**Keywords:** *Forest biodiversity, mitigation, pest control, integrated management*

### **Background**

Around 1 million hectares of *Nothofagus* beech forest in the northern part of the South Island of New Zealand support large populations of native honeydew-producing scale insects. Honeydew provides a major energy source at several trophic levels (birds, lizards and insects). Most honeydew falls to the ground, adding a high load of carbohydrate that affects micro-organisms and hence nutrient cycling. (Beggs et al, 2000). These forests have been progressively invaded by a number of alien species. The most important are wasps (which compete for honeydew and predate insects), browsers (brushtailed possums and red deer) and predators (e.g. stoats, rats and possums).

The Rotoiti Nature Recovery Project has been established to restore a honeydew beech forest ecosystem (as far as possible), with initial focus on an area of 825 hectares, and to use the site for advocacy and education. In the process it seeks to develop improved understanding and management techniques that can be applied to other sites. The project is centred on an intensive, multi-species pest control programme, using an adaptive management approach. It draws on the techniques and lessons from other projects, including both island eradication projects and other pest control projects on the mainland. The use of foodwebs is being explored to enable more accurate modelling of the complex interactions between the alien species and the ecosystem elements, and to allow better targeting of control work.

### **The Project**

#### ***Alien Species Management Work***

##### **Control of Wasps**

Common wasps (*Vespula vulgaris*) are controlled over approximately 300 ha, using an insecticide (Fipronil) mixed with a fish bait and placed in bait stations on a 100x50 m grid. Poison is set out in early summer when worker wasps are foraging on protein. During the two most successful seasons a single application of poison killed over 95% of monitored nests and reduced worker wasp activity by 98-99%.

##### **Control of browsing animals**

Numbers of brushtail possums were reduced by an estimated 94% (comparison of trap catch pre- and post- control) by an initial bait station operation using 1080 bait in over 700 stations placed on a 100mx100m to 150x150m grid. Numbers have been kept at low levels by ongoing poisoning using brodifacoum.

##### **Control of Predators**

Stoats are controlled by 300 Fenn traps set in tunnels with hens' eggs as bait. They are located around the perimeter of the block and on two lines within the block. The numbers caught each year have fluctuated in response to a cycle of beech seeding and related rodent populations. Rats are controlled to low levels by the possum control operation, while numbers have increased dramatically at non-treatment sites.

##### **Monitoring and Research**

The changes brought about by pest control are monitored in the treatment and two non-treatment areas, allowing assessment of the impacts of different control techniques on target pests and native biota. This will increase the efficiency of control at the site, and support transfer of the techniques to other sites.



### *Results for Biodiversity*

#### **Honeydew cycle**

Wasp control has increased the availability of honeydew to well above a target level. When honeydew fell below this level, then native birds were not observed feeding on the resource (Beggs in press). The level in non-control areas was well below the target for a three month period.

#### **Vegetation**

Individual under-storey plants and mistletoes, species which are favoured by possums, are already showing an increase in health and growth. Longer term monitoring is in place to pick up expected changes in forest structure, composition and diversity.

#### **Bird**

Increased productivity has been observed in two bird species subject to detailed study: the kaka (*Nestor meridionalis*) and robin (*Petroica australis*). Kaka nesting success has been 80% in the area subject to predator control, and 10% in the untreated area. The production of young is now considered to be sufficient to compensate for adult mortality, reversing the previous trend towards local extinction of the species (Moorhouse, 2000). Robin nesting success has ranged from 90-95% in the treated area compared to 60% outside. 5 minute bird counts have shown increases in numbers of a wide range of other bird species, including the most common honeyeater (the bellbird) and the other hole-nesting parrot (yellow-crowned parakeet). No comparable increases were observed in the non-treated area.

#### **Invertebrates**

Experiments using artificially placed native caterpillars demonstrated that their survival rate was much higher in the treated area (>35%) compared to the non-treated area (10%). Other research produced similar results when wasp abundance was experimentally reduced (Beggs & Rees, 1999). Wasp density has been kept below a target level derived to protect vulnerable native Lepidoptera (Beggs & Rees 1999).

### *Conclusions*

Initial successes in this project, and the results from similar projects in other forests in New Zealand, suggest that integrated, multi-species intensive pest control can achieve significant improvements in native biodiversity over relatively large areas.

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## INVASIVE SPECIES OF THE IBERIAN PENINSULA: THE VERTEBRATES

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**Key words:** *invasive species, vertebrates, Iberian Peninsula, causes of introductions.*

### Introduction

From historical times, countless introductions have been carried out in the Iberian Peninsula favoured by its geography and the proper history of the country. In the last century, the number of intentional and no intentional introductions of exotic species of flora and fauna has strongly increased. Some of these species have established successfully in the new environment, becoming invasive species, but it is only, in the last years, that their negative effects started to be evident.

These are some of the most important examples:

- *Oxyura jamaicensis*: it competes successfully with the autochthonous *Oxyura leucocephala*, a species classified as Endangered in the Spanish Red Book of Vertebrates (Blanco & González, 1992).
- *Gambusia affinis holbrooki*: it displaces endemic species such as *Aphanius iberus* and *Valencia hispanica* by competing for the same ecological niche (Pena & Domínguez, 1985).
- *Rhynchophorus ferrugineus*: it seriously damages many species of palms due to its trophic and reproductive habits (Esteban-Durán et al., 1998).
- *Caulerpa taxifolia*: it invades and damages the prairies of *Poseidonia oceanica*, significantly altering the ecosystem.

The current research has been mainly focused in agricultural plagues, but the lack of knowledge of the global situation makes urgent the need of an exhaustive study about the presence and distribution of invasive species. The present paper offers a preliminary list of invasive (I) and potential invasive (PI) species of vertebrates of the Iberian Peninsula.

### Results

Among the introduced species of vertebrates, 22 species have been detected as invasive (I) and other 25 as potential invaders which need further detailed studies (See Tables 1, 2, 3, 4). Of the whole list, the 51.06% are freshwater fishes, in front of the 21.28% of birds, the 8.51% of mammals and the 19.15% of amphibians and reptiles. The translocations of autochthonous species have not been considered in the present paper.

The analysis of these introductions reveals that the 34.04% is due to the voluntary release or accidental escape of ornamental species and pets, the 29.79% to the sportive hunting and fishing, the 6.38% to the escape from rearing factories, the 2.13% to sanitary causes and the 27.66% to other causes (involuntary transport, sporadic releases, etc.).

### Conclusions

The present results point out the urgency to get detailed information about the distribution and the effects of invasive species as the basic step for the elaboration of effective control and/or eradication plans. Likewise, the introduction pathways show the lack of information of the population about the consequences of "aliens" introductions. For this reason it is essential to involve the citizen as user/part of the environment by spreading such information in a comprehensible and participative way, to involve who has; in certain way, the possibility/responsibility of avoiding future threats on the biodiversity.

Furthermore, the national legislation should be reinforced to avoid future introductions without previous studies and to allow an efficient control of hunting, fishing and the setting up of rearing factories.

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**Table 1 Preliminary list of invasive (I) and potential invasive (PI) amphibians and reptils.**

FAMILIES	SPECIES	ORIGIN	KEY
BUFONIDAE	<i>Bufo mauritanicus</i>	N Africa	PI
DISCOGLOSSIDAE	<i>Discoglossus pictus</i>	N Africa, S Mediterranean	PI
RANIDAE	<i>Rana catesbeiana</i>	NE America	I
EMYDIDAE	<i>Pseudemys picta</i>	N America	PI
	<i>Trachemys scripta</i>	N America	I
	<i>Trionyx spiniferus</i>	N America	PI
IGUANIDAE	<i>Anolis carolinensis</i>	N America	PI
LACERTIDAE	<i>Podarcis sicula</i>	Italy, Greece, Turkey	PI
	<i>Podarcis dugesii</i>		I

Table 2 Preliminary list of invasive (I) and potential invasive (PI) mammals.

FAMILIES	SPECIES	ORIGIN	KEY
BOVIDAE	<i>Ovis musimon</i>	Asia, Mediterranean Islands	PI
	<i>Ammotragus lervia</i>	Africa	I
CAPROMYDAE	<i>Myocastor coypus</i>	S America	PI
MUSTELIDAE	<i>Mustela vison</i>	N America	I

Table 3 Preliminary list of invasive (I) and potential invasive (PI) birds.

FAMILIES	SPECIES	ORIGIN	KEY
ANATIDAE	<i>Oxyura jamaicensis</i>	N America	I
ESTRILDIDAE	<i>Estrilda melpoda</i>	Subsaharian Africa	PI
	<i>Estrilda astrild</i>	Subsaharian Africa	I
	<i>Estrilda troglodytes</i>	?	PI
	<i>Amandava amandava</i>	Asia	I
	<i>Leiothrix lutea</i>	S Asia	PI
PSITTACIDAE	<i>Myiopsitta monachus</i>	S America	I
	<i>Psittacula krameri</i>	N Africa, Asia	PI
	<i>Aratinga erythrogenys</i>	S America	PI
	<i>Aratinga mitrata</i>	S America	PI

Table 4 Preliminary list of invasive (I) and potential invasive (PI) freshwater fishes.

FAMILIES	SPECIES	ORIGIN	KEY
CYPRINIDAE	<i>Alburnus alburnus</i>	Europe	PI
	<i>Abramis bjoerkna</i>	Europe	PI
	<i>Cyprinus carpio</i>	Eurasia	I
	<i>Scardinius erythrophthalmus</i>	Eurasia	PI
	<i>Carassius auratus</i>	Asia	I
	<i>Tinca tinca</i>	Eurasia	PI
	<i>Rutilus rutilus</i>	Eurasia	PI
ICTALURIDAE	<i>Ictalurus punctatus</i>	?	PI
	<i>Ameiurus melas</i>	N America	I
SILURIDAE	<i>Silurus glanis</i>	Eurasia	I
ESOCIDAE	<i>Esox lucius</i>	Eurasia	I
SALMONIDAE	<i>Hucho hucho</i>	Europe	PI
	<i>Oncorhynchus kisutch</i>	Eurasia, N America	PI
	<i>Oncorhynchus mykiss</i>	N America	I
	<i>Salvelinus fontinalis</i>	N America	PI
FUNDULIDAE	<i>Fundulus heteroclitus</i>	N America	I
POECILIIDAE	<i>Gambusia holbrooki</i>	N America	I
	<i>Poecilia reticulata</i>	C America	PI
CYPRINODONTIDAE	<i>Aphanius fasciatus</i>	?	I
PERCIDAE	<i>Sander lucioperca</i>	Eurasia	I
	<i>Perca fluviatilis</i>	Eurasia	I
CENTRARCHIDAE	<i>Lepomis gibbosus</i>	N America	I
	<i>Micropterus salmoides</i>	N America	I
CICHLIDAE	<i>Cichlasoma facetum</i>	S America	PI

## A REVIEW OF THE LITERATURE ON THE WORLDWIDE DISTRIBUTION, SPREAD OF, AND EFFORTS TO ERADICATE THE NUTRIA (MYOCASTOR COYPUS)

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**Keywords:** *Myocastor coypus*, *coypu*, *nutria*, *wetlands*, *eradication*.

### **Introduction**

We conducted a literature review of nutria (*Myocastor coypus*) introduction and eradication efforts worldwide. The nutria has been introduced from their origins in South America to every continent except Australia and Antarctica. The first attempt at nutria farming occurred in France in the early 1880's, but the first extensive establishment of nutria farms occurred in South America in the 1920's (Evans 1970). The success of these operations led to expansion of nutria farm operations in Europe and North America (Evans 1970). These farms became the source for wild populations of nutria around the world. Nutria often escaped from these farms, or in many cases were deliberately released into the wild in order to provide a game animal and/or remove aquatic vegetation (Kinler 1992, Bounds 2000). In many systems the nutria has become a nuisance species because its feeding activity destroys marsh vegetation, its burrows undermine water control structures, and it feeds on agricultural crops (Litjens 1980). They also have been associated with parasites that affect humans and livestock (Moutou 1997) and can adversely affect other wildlife (Gebhardt 1996). However, in many countries the nutria is considered a welcome resource as a furbearer (Aliev 1967). The classification of nutria as a pest often depends on the price of its pelt (Lowery 1974). High fur prices and subsequent trapping reduces the population, mitigating some of the environmental damage that the nutria can cause and brings money into the local economy (Kinler et al. 1987). Low fur prices usually result in a lower fur harvest, which allows the nutria population to exceed the carrying capacity of their habitat (Gosling and Baker 1987, Kinler et al. 1987). The primary methods of eradication fall into three categories: trapping, poisoning, and shooting (Evans 1970, Gosling et al. 1988, Stevens 1992, Moutou 1997). These methods are often most effective when used in combination with baiting and artificial islands or rafts (Wilner 1982, Baker and Clark 1988, LeBlanc 1994).

### **Regional Accounts**

**Africa:** We could find no comprehensive review of nutria in Africa. Nutrias have been reported in Kenya and in an area of south central Africa where the countries of Botswana, Zambia, and Zimbabwe meet.

**East Asia:** We found no comprehensive reviews of nutria in East Asia. Most of the information was scattered in a variety of sources covering specific countries. The countries where they are known to have been introduced are China, Japan, Korea, Thailand, Taiwan.

**Central Asia and the Middle East:** Nutrias have been introduced throughout central Asia and Israel where they are valued for their fur. The last review of nutria in Asia and the Middle East was by Aliev (1967).

**Europe:** The nutria has been introduced throughout most of Europe. In general, they are considered a pest in western European countries but a resource in eastern European countries where their fur is more valued. Introductions to northern Europe have not been successful. England conducted a successful eradication campaign in the 1980's. Nutria introductions failed in the Scandinavian countries because of harsh winters. The most recent review of nutria distribution in Europe is in Mitchell-Jones et al. (1999).

North America: The nutria is widely established in North America. The first recorded effort to establish a nutria population in North America was at Elizabeth Lake, California, in 1899, which failed because of an inability to reproduce (Evans 1970). The first successful reproduction of farm nutria occurred in Quebec in 1927 (Evans 1970). They have been introduced to 30 states but are currently present in only 15, mostly southern states, Ontario, Quebec, and northern Mexico. The most recent review of nutria distributions in the United States is Bounds (2000).

### *Discussion*

The last worldwide review of nutria was by Aliev (1967). The nutria has been introduced to every continent except Antarctica and Australia, primarily for use as a furbearer. Another reason for nutria introduction has been for the control of weeds (Evans 1970, 1983). Whatever the reason for their introduction, nutria often damage the wetland habitat they inhabit. In years with low pelt prices, the economic damage caused by nutria can far outweigh the economic benefit of their pelts. Economic damage has caused government agencies to implement control or eradication programs to solve the problem (Gosling 1989). The problem these programs face is that nutria are generalist feeders, have a high birthrate, and their habitat requirements are not very rigid (Evans 1983). Because of this, successful control and eradication are often hard to implement.

Cold winters seem to be the most effective mechanism limiting nutria populations in the wild (Stubbe 1992, Bounds 2000). In regions with mild winters and sufficient wetland habitat, eradication has seldom been successful. The best-documented example of eradication of nutria is from England (Gosling 1989). Another successful eradication effort took place in California (Evans 1970). The three conditions needed for a successful nutria eradication efforts are: (1) the population should be isolated from sources of new immigration, (2) inclement weather or harsh conditions are needed to reduce the population, and (3) trapping is continued until no nutria are left.

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## RESEARCH STRATEGIES FOR THE MANAGEMENT OF THE BROWN TREESNAKE ON GUAM

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***Keywords: Boiga irrugetalis, damage, invasion, control***

A complete island ecosystem has been altered, 9 of 12 forest birds have been extirpated, and 7 of 13 lizard species have been extirpated or drastically reduced following the accidental introduction nearly 50 years ago of the Brown Treesnake, *Boiga irregularis*, to Guam. The USGS Brown Treesnake research program, since 1985, has focused on understanding the biology of the Brown Treesnake and its invasion. This research is used to develop tools for effective management of populations on Guam and to prevent its dispersal to other islands or the continental US. Past research has been crucial in identifying probable causes for the success of the snake invasion. Through increased juvenile survivorship, lack of predators, and lack of co-evolution with its prey, the Brown Treesnake has been successful in establishing unprecedented high population densities. Two hundred electrical outages per year are attributable to the Brown Treesnake causing two to four million dollars in lost productivity. Human health factors are also a concern. There have been in excess of 250 emergency room visits for snake bites. Through controlled experimental exclusion of snakes on a small scale, we have shown that snake predation can reduce lizard biomass by nearly one-half. Research has been instrumental in the development and testing of control methods, primarily barriers and trapping. These technologies have been transferred to management agencies and are currently used to prevent Brown Treesnake dispersal, to repatriate Guam Rails and possibly recover other native wildlife.

Although much has been accomplished with this research, the current and ongoing research is manifold. In order to increase the efficacy and scope of control programs and to prevent dispersal, knowledge of the population biology and reproduction is needed. An understanding of snake movements is needed for establishing optimal trapping or other control protocols. Population structure, growth rates and survivorship of juveniles and adults are needed to assess the segment of the population which should be targeted for control and removal. The effect of habitat, prey, and environmental conditions on population densities is necessary to focus which areas are needed for control efforts. This information is also needed to evaluate areas of high risk for invasion. In addition, aspects of reproduction are largely unknown. Knowing the timing and location of reproduction and perhaps how this affects movements of snakes would be crucial to control efforts. The current research outlined above, attempts to provide management agencies the tools needed to effectively manage snakes on Guam and prevent their dispersal.



## CAN PRESCRIBED FIRE SAVE THE ENDANGERED COASTAL PRAIRIE ECOSYSTEM FROM CHINESE TALLOW

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Chinese tallow (*Sapium sebiferum*) is considered by some to be one of the most aggressive invaders of natural terrestrial and wetland ecosystems in the southern United States. Since several of the ecosystems threatened by tallow are fire-maintained, the question has arisen whether fire can act as a controlling agent. The objective of this research was to ascertain the effects of prescribed fires on tallow populations that have established in coastal prairie communities during a period of fire suppression. Studies were conducted to evaluate the critical size hypothesis, which states that tallow trees are only vulnerable to control by fire below some minimum size. Four hundred tree-centered plots were examined to determine the effects of prescribed fire on tallow as a function of (1) season of burn, (2) preburn tree size, (3) fire intensity, (4) fuel conditions, and (5) location along a hydric gradient. Season of burn had little effect on initial damage but long-term impacts were greater for trees subjected to growing season burns. Effects also depended strongly on tree size. Nonetheless, when subjected to intense fire, even the largest trees could be top-killed. Based on these observations, we reject the critical size hypothesis and propose, instead, the critical fuel hypothesis, which states that if fuel conditions are sufficient to produce an intense fire, even the largest tallow trees can be controlled by burning.



## AN INVASIVE SPECIES INFORMATION SYSTEM FOR HAWAII AND PACIFIC ISLANDS

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***Keywords: islands; clearing house***

Biological invasions pose a huge nationwide and worldwide problem that urgently needs innovative approaches toward solutions. Oceanic islands are in general much more susceptible to invasions than continents. No other region of the United States (or of the world) is so devastatingly affected by invasive species as the Pacific. The pervasiveness of this issue for society in Hawaii provides hope that it may be possible to marshal adequate resources to address the problem. Hawaii is in the midst of an invasive alien species crisis affecting the archipelago's highly endemic biota, overall environmental and human health, and the viability of its tourism- and agriculture-based economy.

The gravity of the situation has resulted in approaches that are increasingly recognized as national and global models. The Hawaiian Islands provide an optimal laboratory for dealing with this issue because invasive pest species are a dominant issue in Hawaii right now. Other Pacific islands share Hawaii's vulnerability and have been invaded already to varying degrees. These islands are little fortresses, surrounded by large expanses of ocean. Given rational interagency management based on good science and with the help of informed citizens, the problem can be effectively addressed. In the Hawaiian and Pacific islands, policy makers, managers, scientists, the public, and the media need a recognized clearinghouse for authoritative information and contacts on invasive species issues. This clearinghouse should provide, in a readily accessible format, comprehensive, synthesized information to facilitate sound policy, effective management, and quick action throughout Hawaii and the Pacific.

USGS' Hawaiian Ecosystems at Risk (HEAR) project, started in 1996, provides an excellent start toward such an information clearinghouse. Since 1998, HEAR has been complemented by PIER (Pacific Island Ecosystems at Risk), an invasive species information system for U.S. territories in the Pacific led by the U.S. Forest Service. HEAR ([www.hear.org](http://www.hear.org)) and PIER ([www.hear.org/pier/](http://www.hear.org/pier/)) are already having a substantial impact in facilitating progress in addressing invasions. Helped by injection of funding through the Pacific Basin Information Node of the National Biological Information Infrastructure, starting in 2001, increased infrastructure and manpower are expected to be available to develop more comprehensive information storage, retrieval, and dissemination in cooperation with the Hawaii Natural Heritage Program of University of Hawaii and the Department of Natural Sciences of Bishop Museum. This development should provide a quantum advance for the Hawaii/Pacific invasive species information system, while allowing optimal coordination with the central U.S. national system for invasive species information and with whatever becomes the primary international system.

HEAR provides a mechanism for collection and dissemination of information regarding harmful invasive alien species in Hawaii. HEAR provides information about new invasions and potential risks associated with such invasions, and information to allow good decisions about control of alien species. HEAR's purview also includes collection and dissemination of information to lead to understanding and prediction of pathways of invasion by alien species; to determine effects of invaders and susceptibility of specific areas to invasion; and to assess changes in the distributions and effects of established species.

HEAR's primary target audience to date has been land managers, decision makers, and the general public who are concerned with the impacts of invasive alien species in Hawaii. The information provided by HEAR is useful not only for making decisions locally (in Hawaii), but also throughout the world, especially for islands and tropical areas. HEAR is dedicated to meeting local information needs.

For example, HEAR is a resource available to such groups as the Maui Invasive Species Committee (MISC) (<http://www.hear.org/misc>) to announce and post the proceedings of their activities, as well as to provide information from a variety of international sources about species identification, potential problems created by, and control of newly-discovered incipient species. HEAR's formal and informal cooperative network extends to dozens of organizations and individuals; such a network provides benefits both to HEAR and to the cooperators. HEAR's priorities are responsive to needs of local, state, and national stakeholders.

Ultimately, all information collected by HEAR is slated to be available on the HEAR website (<http://www.hear.org>). Recently, number of hits and number of repeat visitors to the HEAR website have been increasing; in June 2000, the HEAR website received over 24,000 hits from over 5,000 unique visitors. At least 65% of the hits are from the U.S.; 14% or more are from international users.

Although HEAR is driven by local information needs, HEAR is actively involved with national programs and international groups (e.g. IUCN's Invasive Species Specialist Group, GISP) to ensure that its audience receives the benefits of all levels of information, planning, and programs. For example, HEAR is actively involved in working towards providing its expertise and information to national/international efforts to create internet-based distributed alien species databases. HEAR also acts as a liaison between the local groups and national/international groups, facilitating two-way information flow between local and larger-perspective groups. This communication ensures that HEAR remains on the right track with respect to the "big picture", and contributes meaningfully to the local, national, and worldwide information infrastructure regarding invasive alien species.

Because of the success of the Hawaiian Ecosystems at Risk project to date in Hawaii at providing information and information infrastructure to meet local and other data needs with respect to invasive alien species, we believe HEAR would be a good model for similar endeavors nationwide and internationally.

## WHY NOT ERADICATION? – DON'T AIM TOO LOW IN INVASIVES CONTROL?

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### *History*

Eradication of invasive non-indigenous species is often viewed as an impossible goal and an approach typified by high-profile failures, such as the expensive, disastrous attempt to eradicate the imported fire ant from the United States. By default, maintenance management, usually biological or chemical control, is generally attempted instead. However, many animals, plants, and even microorganisms have been eradicated. Although most successes concerned geographically circumscribed invasions (e.g., on small islands), others have rid substantial continental areas of invaders (e.g., *Anopheles gambiae* from northeastern Brazil, screw-worm from much of North America, or smallpox from the entire earth).

### *Prerequisites for success*

Successful eradications share three features: (1) Sufficient economic resources must exist for the project to be completed. (2) Clear lines of authority must exist; someone must be in charge and must be able to compel cooperation. (3) The biology of the target organism must be adequately researched and appropriate. Although there are far more successful eradications of animals (especially insects and mammals) than of plants, this difference is probably more a function of lack of sustained effort on most plants rather than inherently greater biological impediments to eradication.

For many eradication attempts, probability of rapid reinvasion must be low for success to ensue. However, a benefit-cost analysis can indicate that an eradication campaign is appropriate even if reinvasion is likely. An eradication campaign plagued by continual reinvasion can nevertheless be a strong inspirational tool in the overall battle against nonindigenous invaders if it enlists public support and generates publicity. For example, many school children have been engaged in "broom bashes" to remove Scotch broom in British Columbia. Even when eradication is feasible, a benefit-cost analysis may indicate it is not the best management strategy.

Even when the above criteria are met, an eradication attempt, even if successful, can lead to unforeseen problems, such as mesopredator release or a proliferation of exotic weeds at the expense of native plants. Finally, not only can attempted eradication of widely distributed invaders be costly, but it can generate nontarget impacts (e.g., on human health or species of conservation concern), the importance of which will be weighed differently by different stakeholders. Eradication campaigns that benefit primarily agriculture (e.g., the attempts to eliminate the medfly in California and Florida) are especially likely to engender wide opposition. When human health is an issue, the public is more likely to accept substantial costs and inconvenience. Thus, successful eradication may be as much a function of political skill and public education as of technology. Some eradications can be easily sabotaged by individuals opposed to the campaign.

### ***Why is eradication not attempted more often?***

To date, eradication has been a rather idiosyncratic matter, often resting on the drive and ingenuity of one person or a few people. This has partly been a problem of generally insufficient attention paid to invasions. Other developments in management of invasions should increase the appeal of eradication attempts. The evolution of more comprehensive monitoring and reporting systems, as well as more rapid response procedures, should lead to the more frequent eradication of invasions before they become metastatic. However, even invasions that escape initial elimination and spread widely may be susceptible



to eradication. Many invasions that would, a priori, appear suitable by the above criteria for eradication have not been attacked because no one has mustered the enthusiasm to try it or generated the political support to provide the necessary resources and framework. The scattered and gray literature on eradication is another impediment; people working on plants, animals, and pathogens are often unaware of developments in techniques to eradicate their own taxa, much less unrelated species. In general, we do not know the geographic limits of current technologies. For example, just how great an investment would be required to rid a large island or substantial continental region of a pestiferous mammal or a horrendous weed? Many invasion managers seem unaware of the possibility of employing large numbers of volunteers or paid or convict labor to try to eradicate a pest. As with many other aspects of the invasion problem, eradication may largely be a victim of an unwarranted defeatism about invasions that could generate the very outcome that is most feared – in fact, we are not doomed to the biotic homogenization of the earth. But we will surely lose this war if we do not aim higher.

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## THE CONTRIBUTION OF TAXONOMY TO ASSESSING INVASIVE SPECIES

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### ***Introduction***

Taxonomy has a core role in supporting implementation of the Convention on Biological Diversity (CBD). It lies at the root of knowledge on biodiversity, providing a reference system that underpins planning and action, whether on forests, invasive species or other key issues. Museums such as The Natural History Museum, in partnership with scientists, governments and communities in many countries, are essential to achieve the objectives of the Global Taxonomy Initiative and the wider objectives of the CBD.

In many cases the precise number and identity of introduced species is unknown and data on their distribution, rate of spread and other information are equally scant. As a first step to providing data, a biodiversity inventory is required in collaboration with taxonomists and local expertise. This not only records the taxa (native and introduced) present but acts as an identification tool, allowing others to record more detailed information on a variety of taxa. In addition, new scientific advances are changing the way in which we think about invasive species - the traditional approach of morphological taxonomy must continue to be developed, but we are now coming to terms with more subtle concepts of invasion, in terms of genetic intrusion of an introduced species into wild populations.

### ***Research Expertise and Collections***

Research on biodiversity relies on the great reference collections of museums. The Natural History Museum's collections are unique in their coverage of many areas of the world, and are particularly important for regions that are rich in biodiversity, but where there are few taxonomists. The Museum has active collaborative research and collections development with a number of countries. This work ranges from the fundamental naming and classification of organisms, to the provision of information systems and products to meet local needs.

### ***Case Study 1. Introgression and Genetic Erosion: the Galapagos Tomato (Solanum cheesmaniae)***

Genes from rare endemic species are not only of interest to the conservation of biodiversity but can also be of commercial importance. For example, genes from the Galapagos tomato (*Solanum cheesmaniae*) have been used by plant breeders to improve the cultivated tomato *S. lycopersicum*. Recent observations have however suggested that these island populations of *S. cheesmaniae* are under threat from feral populations of the introduced cultivated tomato. The Natural History Museum in collaboration with University College London, and the Charles Darwin Research Station are carrying out work on the potential hybridisation between the endemic and the introduced species which will enforce the links between taxonomy and conservation (especially Articles 8, 9, 15 and 17 of the CBD).

### ***Case Study 2. The Chinese Mitten Crab: an Invasive Species in Europe***

*Eriocheir sinensis*, the Chinese mitten crab, is a native of east Asia living predominantly in freshwater but migrating seaward to breed. In 1912 a large male was collected in the River Aller, a tributary of the Weser, Germany and now this invasive species has a European distribution from Finland to the Atlantic coast of France. In England, the mitten crab has been reported from the Humber, Medway and Thames. The

Museum is conducting research on the development of populations of this invasive crab and their environmental effects, (see <http://www.nhm.ac.uk/zoology/crab/>). The mitten crab burrows into river banks and is a hazard to ecosystems. The crab is capable of emerging from water and crossing dry land to enter new river systems. This invasion could eventually threaten populations of native species by destroying habitat (for example the crayfish *Austropotamobius pallipes* in the UK).

### ***Information Provision***

The Museum is directing greater efforts in information provision to meeting specific needs for information on biodiversity, ranging from education and awareness, to research or practical action. The outputs in this area range from simple field guides in local languages to the larger monographs such as the *Flora Mesoamericana*, more details of which can be seen at [www.nhm.ac.uk/botany/projects\\_research/project1/index.html](http://www.nhm.ac.uk/botany/projects_research/project1/index.html). Without reliable baseline information, founded on rigorous science, attempts to understand and act on invasive species are often less than effective.

Specimen information is important in monitoring the spread of invasive species. Access to databases of this specimen level information (such as location and date of collection) is being investigated in international initiatives, involving collaboration between institutions and users on common standards and integrated approaches. European funding is supporting a pilot, The European Natural History Specimen Information Network (ENHSIN [www.nhm.ac.uk/science/enhsin](http://www.nhm.ac.uk/science/enhsin)), with the goal of developing unified information on collections originating from many parts of the world.

### ***Case Study 3. Information for Effective Action on Invasives in Vulnerable Island Ecosystems***

Many native taxa that occupy specific niches and have narrow tolerances and are readily out-competed by aggressive invaders. A combination of small populations (giving no reservoir for repopulation) and limited land area (giving few refuges for native species) often prevents any future recovery. Madeira and the Azores are part of the floristic region of Macaronesia, four groups of volcanic, oceanic islands that are isolated from the mainland and have high levels of endemism. The islands have a history as important stop-over points on major trade routes and large numbers of exotic species from all parts of the world have been introduced accidentally or deliberately, bolstering the number of species present. Alien species are estimated to make up 60-75% of the Azorean vascular flora.

The Natural History Museum is actively involved in several projects in Macaronesia. These range from inventories of flowering plants, ferns and lichens and surveys of habitats, to examination of historical records, population studies to determine colonisation events and systematic studies of native and introduced taxa. Such floristic work supports conservation by:

- providing baseline conservation information (identifying invasive species, the species which are threatened and the rate at which exotics spread)
- delivering information to policy makers, conservationists, agriculture, and the general public.

### ***Training, Education and Capacity Building***

A key area of development within CBD is the development of taxonomic skills, upon which effective action on invasive species depends. This is achieved by contributing to the training of specialist taxonomists in many parts of the world and by organising a specialist MSc course on Advanced Methods in Taxonomy and Biodiversity, and collaborating with universities in the UK and elsewhere on supervision of research students.

(<http://www.nhm.ac.uk/science/rco/postgrad/general/postgradindex.html>)

***Case Study 4. Training for Identification of Peach Fruit Fly, *Bactrocera zonata* (Saunders), in The Eastern Mediterranean***

The peach fruit fly, *Bactrocera zonata*, is native to South Asia, where it attacks a wide variety of soft fruits, e.g. peach, guava and mango. It is not known exactly when it spread to the Middle East, but there is a record from Saudi Arabia dated 1982, and more recently it has been found in Oman. By the late 1990s it was well established in Egypt. This species went misidentified for several years, and which is estimated to account for \$177m losses a year. The Natural History Museum has been working with the Natural Resources Institute to develop identification tools to help extension workers and others in the eastern Mediterranean recognise the peach fruit fly, as a foundation for effective control measures. (<http://www.iaea.org/programmes/nafa/d4/public/zonata.html>)

## Fungal Invaders

*P.Johnston & P.Buchanan*

The ectomycorrhizal *Amanita muscaria* and the wood-rotting *Favolaschia calocera* are both known to have been introduced to New Zealand in historically recent times. Both species are invading native forests at some sites, unusual for fungi introduced to New Zealand. We have initiated a programme to determine the distribution of these two species in New Zealand's native forests, and to ask the questions: what are the biological consequences of these invasions? and, what characteristics allow some exotic fungal species to invade indigenous ecosystems? Although these species are not plant pathogens, they have the potential to displace native species from the communities in which they occur, to disrupt natural fungal successions in those communities, and perhaps to disrupt the food chains of indigenous invertebrates.

## Invasive Weeds in forest ecosystems

*R.Harris, P.Williams, R.Toft, & B.Karl*

There are relatively few lowland forest remnants in New Zealand. Most are small fragments that have been modified by selective logging, grazing and edge effects. As a result they are often invaded by exotic weeds, particularly vines and forest floor herbs. We have undertaken research to determine the impact of three invasive weeds on forest community structure, function and biodiversity, and to determine what these impacts may mean for the long-term viability of these systems.

## Biological control of environmental weeds in New Zealand

*S.Fowler, R.Hill, P.Syrett*

Control of alien weeds invading natural or semi-natural habitats can be difficult. Classical biological control offers a complete or partial solution to some alien weed problems by introducing host specific natural enemies from the native range of the weed. We review advantages of biocontrol, safety testing of biocontrol agents, successes achieved in New Zealand and challenges for the future.



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