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The Great Reshuffling

Human Dimensions of Invasive Alien Species

Edited by Jeffrey A. McNeely

IUCN
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Preface

Expanding international trade is moving ever more organisms more rapidly around the world, thereby increasing the threat that some of these species could be harmful to native ecosystems and human economic interests. So many goods are moving so quickly that government efforts to prevent unwanted invasions are being overwhelmed. In response to these concerns, the Global Invasive Species Programme (GISP) was developed beginning in January 1996. Formally established in 1997, GISP is operated by a consortium of the Scientific Committee on Problems of the Environment (SCOPE), CABInternational (CABI), the World Conservation Union (IUCN), and the United Nations Environment Programme (UNEP). GISP is a component of DIVERSITAS, an international programme on biodiversity science. The goal of GISP is to enable governments and other organizations to use the best practices available to control Invasive Alien Species (IAS) and to promote the development of additional tools and strategies needed to improve global management of IAS.

With funding from many sources, GISP seeks to improve the scientific basis for decision making on invasive species; develop capacities to employ early warning, rapid assessment and response systems; enhance the ability to manage invasives; reduce the economic impacts of invasives and control methods; develop better risk assessment methods; and strengthen international agreements. GISP strives to develop public education about invasive species, improve understanding of the ecology of invasives, examine legal and institutional frameworks for controlling invasives, develop new codes of conduct for the movement of species, and develop new tools for quantifying the impact of invasives. GISP's work involves dozens of scientists, lawyers, and resource managers from all parts of the world. More information about GISP can be found at its Website: http://jasper.stanford.edu/gisp.

GISP recognizes that it is dealing with dynamic ecosystems; it does not advocate attempts to "freeze" any particular ecosystem in an imagined pristine state. Rather, it realizes that active management of human effects on ecosystems is required in a time of increasing human impact. This book is one product of Phase I of GISP and is designed to explore some of the human dimensions of the problem of invasive alien species.

As part of the GISP Programme, a workshop on these human dimensions was held in Cape Town, South Africa on 15 to 17 September. The overall management of the GISP process was in the capable hands of Professor Harold Mooney of Stanford University, with very able support from Laurie Neville. Veronique Plocq-Fichelet provided steadfast support from ICSU-SCOPE in Paris. The workshop would not have been possible without the support of Jamie Reaser, from the US Department of State. The US Department of State provided the main financial support to enable the workshop to be held, while the Swiss Development Cooperation (SDC) provided additional financial support. At the Cape Town workshop, Guy Preston of the Working for Water Programme was responsible for making the workshop facilities available and providing very considerable logistics support. Karoline Hanks, Gadija Williams, Dumi Magadlela and Simone Noemdoe, from the Working for Water Programme, played essential roles in making the Cape Town workshop a success. Phyllis Windle kindly acted as rapporteur and synthesizer at the Cape Town workshop. We are all very grateful as well to Brian Huntley for his outstanding hospitality at Kirstenbosch National Botanical Garden in Cape Town. The production of these proceedings depended very much on Sue Rallo, who was responsible for managing the production process and handling all correspondence. I received useful comments from Channa Bambaradeniya, Pierre Binggeli, Maj de Poorter, Llewellyn Foxcroft, Piero Genovesi, Johan Hattingh, Peter Jenkins, David Le Maitre, Tim Low, Dick Mack, Jamie Reaser, Dave Richardson, George Staples, Mark Williamson and Phyllis Windle. Pierre

Binggeli performed beyond the call of duty in helping especially with the references. Joseph McNeely served as research assistant. To all of these, and of course the other participants at the workshop, I owe a personal debt of thanks. I hope that the ideas put forward in this volume will help ensure that invasive alien species issues begin to get their appropriate level of attention in the on-going debate about the social, economic, ecological, and political impacts of globalization.

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Definitions of key terms

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

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

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

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

GMO/LMO: A genetically-modified organism/living modified organism is a species whose genetic makeup has been purposefully altered by human technology. When the resulting organism is sufficiently different from its nearest relative to be considered a "new species", then it can be considered an alien species. These are addressed under Article 8(g) of the Convention on Biological Diversity.

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

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

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

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

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

Pest: "Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products" (definition of International Plant Protection Convention).

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

Unintentional introduction: a species utilising unwitting humans or human delivery systems as vectors to disperse and become established outside its natural range (IUCN, 2000).

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

An introduction to human dimensions of invasive alien species

Jeffrey A. McNeely

Abstract

While the issue of invasive alien species has important biological components, the human dimensions deserve much greater attention. First, virtually all of our planet's ecosystems have a strong and increasing anthropogenic component that is being fed by increasing globalization of the economy. Second, people are designing the kinds of ecosystems they find productive or congenial, incorporating species from all parts of the world. Third, growing travel and trade, coupled with weakening customs and quarantine controls, mean that people are both intentionally and inadvertently introducing alien species that may become invasive. And fourth, the issue has important philosophical dimensions, requiring people to examine fundamental ideas, such as "native" and "natural". The great increase in the introduction of alien species that people are importing for economic, aesthetic, accidental, or even psychological reasons is leading to more species invading native ecosystems, with disastrous results: they become invasive alien species (IAS) that have significant deleterious effects on both ecosystems and economies. This introductory chapter examines some of the important human dimensions of the IAS problem, including historical, economic, cultural, linguistic, health, psychological, sociological, management, legal, military, philosophical, ethical, and political dimensions. These are addressed in terms of the causes, the consequences, and the responses to the problem of IAS. Many of these are discussed in considerable detail in other papers in this volume, but it is apparent from this introduction that the human dimensions of IAS are fundamental, and that successfully addressing the problem will call for greater collaboration between different economic sectors and among a wide range of disciplines. The Convention on Biological Diversity and many other international agreements offer important opportunities for addressing the complex global problems of IAS through improved international cooperation.

Introduction

Human impacts on the ecosystems of our planet continue to grow. Our increasing population and expanding levels of consumption mean that more people are consuming more of nature's goods and services, pushing against the limits of sustainability. Greatly expanding global trade is feeding this consumption, with large containers of goods moving quickly from one part of the world to another by plane, ship, train, and truck.

One critical element in this economic globalization is the movement of organisms from one part of the world to another through trade, transport, travel, and tourism. Many of these movements of organisms into new ecosystems where they are alien (also called non-native, non-indigenous or exotic) are generally beneficial to people. But many others have very mixed impacts, benefiting some individuals or interest groups while disadvantaging others. And in a

few cases, especially disease organisms and pests of forests or agricultural crops, the alien species is clearly detrimental to all, or nearly so. This book addresses the latter groups: "Invasive alien species" (IAS), that subset of alien species whose establishment and spread threatens ecosystems, habitats, or species with economic or environmental harm (GISP, 2001).

Farmers have been fighting weeds since the very beginnings of agriculture, and disease organisms have been a major focus of physicians for well over a hundred years. But the general global problem of invasive alien species has been brought to the world's attention only relatively recently by ecologists who were concerned that native species and ecosystems were being disrupted (e.g., Elton, 1958; Drake *et al*., 1989). Much of the work to date on IAS has focused on their biological and ecological characteristics, the vulnerability of ecosystems to invasions, and the use of various means of control against invasives. However, the problem of IAS is above all a human one, for at least the following reasons:

- People are largely responsible for moving eggs, seeds, spores, vegetative parts, and whole organisms from one place to another, especially through modern global transport and travel;
- While some species are capable of invading well-protected, "intact" ecosystems, IAS more often seem to invade habitats altered by humans, such as agricultural fields, human settlements, and roadways;
- Many alien species are intentionally introduced for economic reasons (a major human endeavour), implying that those earning economic benefits should also be responsible for economic costs should the alien become invasive; and
- The dimensions of the problem of invasive alien species are defined by people, and the response is also designed and implemented by people, with differential impacts on different groups of people.

People introduce organisms into new habitats non-intentionally (often invertebrates and pathogens), intentionally (usually plants and vertebrates), or by inadvertence when organisms imported for a limited purpose then subsequently spread into new habitats (Levin, 1989). Many of the deliberate introductions relate to the human interest in nurturing species that are helpful to people, for agricultural, forestry, ornamental, or even psychological purposes (Staples, this volume). The great bulk of human dietary needs in most parts of the world are met by species that have been introduced from elsewhere (Hoyt, 1992); it is difficult to imagine an Africa without cattle, goats, maize, and cassava, or a North America without wheat, soy beans, cattle and pigs, or a Europe without tomatoes, potatoes, and maize – all introduced species. Species introductions, therefore, are an essential part of human welfare and local cultures in virtually all parts of the world. Further, maintaining the health of these introduced alien species of undoubted net benefit to humans may sometimes require the introduction of additional alien species for use in biological control programmes which import natural enemies of, for example, agricultural pests (Waage, 1991; Thomas and Willis, 1998), but these biological controls may themselves sometimes become invasive.

Considerable evidence indicates a rapid recent growth in the number and impact of IAS (Mooney and Hobbs, 2000). Trade, and more generally economic development, lead to more IAS; Vilà and Pujadas (this volume), for example, found that countries that are more effectively tied into the global trading system tend to have more IAS, being positively linked to the development of terrestrial transport networks, migration rates, number of tourists visiting the country, and trade in commodities (Dalmazzone, 2000). The general global picture shows tremendous mixing of species, with unpredictable long-term results but a clear trend toward homogenization (Bright, 1999; Mooney and Hobbs, 2000). The future is certain to bring considerable additional species shuffling as people continue to influence ecosystems in various ways, not least through both purposeful and accidental introduction of species as an inevitable consequence of growing global trade. This shuffling will yield species that become more

abundant and many others that will decline in numbers (or even become extinct), but the overall effect will likely be a global loss of biodiversity at species and genetic levels. But how is the "great reshuffling" of species being driven by human interests and how will it affect them? How should people think about the issue? What stakes are involved? Whose interests are being affected? How can the human dimensions be best addressed by scientists, resource managers, and policy makers?

These are not trivial questions, because the issue of IAS has ramifications throughout modern economies. It involves global trade, settlement patterns, agriculture, economics, health, water management, climate change, genetic engineering and many other fields and concerns. It therefore goes to the very heart of problems policy-makers are spending much time debating, ironically usually without reference to IAS. This book examines some of the ramifications of IAS through many dimensions of human endeavour, including historical, economic, cultural, linguistic, health, psychological, sociological, legal, management, military, philosophical, and political components. It shows that IAS are deeply woven into the fabric of modern life. While the biological dimensions of IAS are fundamental, more effective responses to the problems they pose must incorporate the kinds of human dimensions that are discussed in this book. This introduction provides an overview and synthesis of some of the key issues.

Historical dimensions

Because of a long geological and evolutionary history, our planet has very different species of plants, animals, and micro-organisms on the various continents, and in the various ecosystems. As a broad illustration, Africa has gorillas, Indonesia has orangutans, South America has monkeys but no apes, and Australia has no non-human primates at all. Even within the continents, most species are confined to particular types of habitats; gorillas live in forests, zebras mostly in grasslands, and addax in deserts. Oceanic islands and other geographically-isolated ecosystems often have their own suites of species, many found nowhere else (termed "endemic species"); about 20% of the world's flora is made up of insular endemics, found on only 3.6% of the land surface area. Geographical barriers have ensured that most species remain within their region, thus resulting in a much greater species richness across the planet than would have been the case if all land masses were part of a single continent. This historical biogeographical framework provides the basis for defining concepts of native and alien species. It is also important to recognize that biogeography is dynamic, as species expand and contract their ranges and the contents of ecosystems change as a result of factors such as climate change (Udvardy, 1969).

Humans apparently evolved in Africa, then *Homo sapiens* spread to Europe and Asia over 100,000 years ago, Australia 40-60,000 years ago, the Americas about 15-20,000 years ago, and the far reaches of the Pacific less than 1000 years ago. Our species is a good example of a naturally invasive species, spreading quickly, modifying ecosystems through the use of fire, and driving other species to extinction (Martin and Klein, 1984). Wherever people have moved they have also carried other species with them. The Asians who first peopled the Americas, for example, were accompanied by dogs, and Polynesians sailed with pigs, taro, yams, and at least 30 other species of plants (and rats and lizards as stowaways).

Trade is known far back in human prehistory, judging from the discovery of stone tools at a considerable distance from where they were quarried. But as long-distance travel became more regular, trade became more important. Chinese traders have spread into Southeast Asia for at least several thousand years, and trading routes between India and the Middle East stretch back at least as long. As sailing craft became larger and more reliable, trade increased further and was given a great boost with the voyages of Christopher Columbus that opened up entirely new

sources of species, and led to the replacement of the rigid moral strictures of Medieval Europe by a new set of merchant values that stressed consumption (Low, this volume).

For at least several thousand years, armies have been an important pathway for moving species from one region to another, with at least some of these becoming invasive (like the armies). The spread of new diseases by armies is well known. For example, measles were carried into the Americas from Europe by the early conquistadors and perhaps syphilis went in the opposite direction (McNeill, 1976). Rinderpest, a virus that is a close relative of measles and canine distemper, is native to the Steppes of Central Asia, but it frequently swept through Europe, being carried by cattle moved to feed armies during military campaigns. Africa remained free of this disease until 1887, when it appeared in Eritrea at the site of the Italian invasion, spreading through Ethiopia in 1888 and conquering the entire continent in less than a decade. In some parts of Africa, rinderpest was followed by wars and cattle raids as the tribal pastoralists sought to maintain their herds (Pearce, 2000). Another result was that rinderpest led an ecological revolution against people and cattle and in favour of wildlife species that were resistant to the disease.

The period of European colonialism ushered in a new era of species introductions, as the European settlers sought to recreate the familiar conditions of home (Crosby, 1986). They took with them species such as wheat, barley, rye, cattle, pigs, horses, sheep, and goats, but in the early years their impacts were limited by the available means of transport. Once steam-powered ships came into common use, the floodgates opened and over 50 million Europeans emigrated to distant shores between 1820 and 1930, carrying numerous plants and animals that were added to the native flora and fauna (Reichard, this volume). More recently, Chinese, Indian, Indo-Chinese, African, and other emigrants have carried familiar species with them to grow in their new homelands in Europe, Australia, and the Americas.

The era of European colonialism also saw the spread of plant exploration, seeking new species of ornamental plants for botanical gardens, nurseries, and private individuals back home (Reichard, this volume). The spread of global consumerism was given a significant boost in the early decades of the 20th century through advertising and marketing that was strategically designed to motivate the public to buy more goods (Staples, this volume). This ultimately led to an accelerating search to find new species to grow and market, creating consumer demand for products that previously were not present. The invasive characteristics of the newly introduced species often came as a surprise, because those responsible for the introduction were unaware of the possible negative ecological ramifications of the species involved.

Many invasive species of plants and animals were carried by the colonial military, especially to Pacific and Indian Ocean islands that had numerous endemic species vulnerable to these invasives. In the 17th and 18th centuries, navies introduced many plants and animals to remote islands as future food sources, and these frequently became invasive (Binggeli, this volume). The military sometimes brought in exotic species of plants to form barriers. For example, the French introduced a cactus (*Opuntia monacantha*) to Fort Dauphin in southeast Madagascar in 1768 to provide an impregnable barrier around the fort. Later, the military also introduced a spineless variety (of *O. ficus-indica*) to feed oxen (Decary, 1947). The role of the military in the spread of IAS has continued. World War II was a particularly active time for the introduction of weeds in the Pacific. Some species, such as Bermuda grass (*Cynodon dactylon*), were deliberately introduced to revegetate islands that were devastated by military activity. Many species spread by accident, clinging to military equipment and supplies or sticking to wheels of airplanes. Some species of grasses were carried from one island to another as seeds adhering to clothing. And because many weeds do best on bare or disturbed ground, war helped to prepare a fertile ground for them. The brown tree snake (*Boiga irregularis*) came to Guam from New Guinea or the Solomon Islands during the War, apparently hitching a ride on either Allied or Japanese ships or planes. Arriving in Guam, the brown tree snake found that the local birds and

lizards were not well adapted to such an agile predator armed with poison fangs; as a result, the populations of native birds and lizards have plummeted on Guam. Now the brown tree snake is threatening Hawaii, potentially carried by military transports from Guam.

Thus the faunal and floral assemblages found in any particular location have been profoundly influenced by past human activities, and people are likely to have an even greater impact in the future. This leads to the contemplation of whether the current episode of globalization might lead to increased diversity in at least some places after the dust settles on the current extinction spasm (Parker, this volume). As just one example, New Zealand has twice as many plants today as it did when humans first arrived, as well as a whole suite of new mammals; one tragic cost was the loss of an extensive unique fauna of birds. Further development of biotic communities as climates change will depend on organisms invading into novel habitats, sometimes hybridizing with the native species, sometimes replacing them, and sometimes adding to the diversity of the ecosystem with new species interactions. Through introducing species, humans are creating their own ecosystems (Orr and Smith, 1998), often more or less by accident, and disrupting ecosystems that had evolved over millions of years.

Human dimensions of the causes of species invasions

Global trade has enabled modern societies to benefit from the unprecedented movement and establishment of species around the world. Agriculture, forestry, fisheries, the pet trade, the horticultural industry, and many industrial consumers of raw materials today depend on species that are native to distant parts of the world. The lives of people everywhere have been greatly enriched by their access to a greater share of the world's biological diversity, and expanding global trade is providing additional opportunities for further such enrichment. Most people warmly welcome this globalization of trade, and growing incomes in many parts of the world are leading to increased demand for imported products. North American nursery catalogues, for example, offer nearly 60,000 plant species and varieties to a global market, often through the Internet (Ewel *et al*., 1999). A generally unrecognized side effect of this globalization is the introduction of alien species, at least some of which may be invasive.

Global mobility has undermined the sense of place that previously provided a psychological anchor to most societies. Modern information technology leaves us "with the disorienting experience that there is no single or universal context with clearly defined borderlines within which we can appeal to reason to settle our differences, but rather a multiplicity of mini-contexts that are not universally shared within which numerous incommensurable interpretations co-exist alongside one another" (Hattingh, this volume). The speed at which many modern people live, including great mobility, seriously compromises their ability to develop a sense of place, a clear vision of the future, or a sense of origin. This makes it much more difficult for people to distinguish between native and alien species, or to be concerned about the difference.

Linked to the global marketplace, the world is becoming increasingly urban, with half the world's population living in cities at the turn of the century. Cities tend to be the focal points of the global economy and the entry points for many invasives. Many invasive species are most prolific in urban and urban-fringe environments where long histories of human disturbance have created abundant bare ground and many opportunities for invasion. Many urban dwellers seek ornamentals from a wide range of sources, and these may become invasive. For example, Berlin has 839 native species of plants and 593 aliens (Kowarik, 1990). Urbanization involves large and mobile populations that can easily escape the environmental penalties from mis-using resources. Further, they are seldom aware of the problems of invasive species because they have essentially lost their connections to the natural environment (Staples, this volume).

Settlement patterns also involve transportation links, and the distribution of many invasives seem to follow transportation corridors. Thus human settlement patterns, too, are part of the invasive species issue (Marambe, *et al*., this volume).

Many people who seek to introduce a non-native species into a new habitat do so for an economic reason (McNeely, 1999). They may wish to increase their profits from agriculture, they may believe that the public will like a newly-discovered flower from a distant part of the globe, or they may think that non-native species will be able to carry out functions that native species cannot carry out as effectively. But few of those introducing alien species have carried out a thorough cost-benefit analysis before initiating the introduction, ignoring ("externalizing") the negative impacts that may follow from species introductions because they have not been required to recognize them. They might also be worried that they would be expected to compensate those who are negatively affected.

Similarly, those who have been responsible for inadvertently introducing species into new habitats may not have been willing to make the investment necessary to prevent such accidents from occurring. They may not have realized the dangers, and in any case the dangers would be unlikely to have much economic impact on their own welfare. Rather, the costs of such accidents are borne disproportionately by people other than those who are permitting the accidents to happen. Thus the costs of introducing potentially invasive alien species into new habitats are externalized in considerations of the costs of global trade. The line of responsibility is insufficiently clear to bring about the necessary changes in behaviour, so the general public and future generations end up paying most of the costs.

In the early 1990s, Serbian scientists discovered the western corn rootworm (a beetle *Diabrotica vigifera*, whose worm-like larvae feed on the roots of maize plants) near Belgrade airport, apparently inadvertently flown in on military aircraft from the USA. Vigorous international action might have curbed this pest's first known venture outside North America, but the turmoil of war prevented such a collaboration and now it is too late. By 1995, the pest had spread into Croatia and Hungary, subsequently invading Romania, Bosnia-Herzegovina, Bulgaria, and Italy (Enserink, 1999). It is likely eventually to spread into every maize-planting country in Europe, and perhaps eventually into Asia, forcing farmers to use chemical pesticides. A problem that would have been relatively easy and cheap to solve if addressed quickly was prevented from being controlled due to the human factor of war that blocked the necessary collaboration, and the problem now has serious economic impacts.

One limitation of human perception of the costs of IAS is that invasions often happen almost invisibly, without any clear responsibility, and with very limited initial impacts. Further, monitoring, early detection, and containment of invaders before they cause widespread damage are unlikely to be considered to have a positive cost-benefit ratio because the costs are required now while the main benefits (at least in terms of future costs avoided) remain speculative. On the other hand, where sound cost-benefit studies have been done, they demonstrate the value of control, and prevention is shown to be the best strategy (Jenkins, this volume).

Practically all human cultures actively modify their surroundings to achieve an environment that they find pleasing. At least part of the world's cultural diversity is due to the local patterns of distribution of plants and animals, because the locally-available resources and how they are used help to define the character of any particular cultural group. Some IAS become part of the local culture. For example, Australian Aborigines today are hunting some of the mammals that have invaded Australia (such as water buffalo, rabbits and camels) and they argue that the government programmes to control these invasive aliens in the name of protecting native fauna and flora are affecting an important food source for them. They contend that they are thus being forced to turn their hunting attention to native species that are already under threat.

The Maori people of New Zealand have similar concerns. For example, some Maori leaders initially opposed eradication of Pacific rats (*Rattus exulans)* from some islands, claiming that they were "a treasure" brought to New Zealand by their ancestors in the course of their

migrations (Veitch and Clout, this volume). While neither Maoris nor Aborigines have a single perspective on IAS, they share a concern about the use of poisons to control IAS, the potential for pollution of water supplies, and the introduction of yet more alien species for biological control.

Some suggest that people have an innate tendency to focus on life and lifelike processes, a condition Wilson (1984) called "biophilia". This leads many people to value diversity for its own sake, perhaps seeking to enhance the options available for improving their physical or social well-being. One manifestation of this tendency may be a need or desire to have other, non-human, species living close to us (Mack, this volume; Staples, this volume). In the USA, China, Europe and elsewhere, a thriving pet trade that answers this human need also poses continuous risks due to intentional or accidental releases by pet owners (see, for example, Genovesi and Bertolino, this volume). Even people who are professional resource managers, such as the staff at South Africa's Kruger National Park, can be remarkably resistant to the idea of limiting their cultivation of potentially invasive garden plants (Foxcroft, this volume). Thus human preference rather than biological traits may have the primary importance in determining whether a plant or animal species is intentionally introduced.

Human dimensions of the consequences of invasive alien species

IAS have many negative impacts on human economic interests. Weeds reduce crop yields, increase control costs, and decrease water supply by degrading catchment areas and freshwater ecosystems. Tourists unwittingly introduce alien plants into national parks, where they degrade protected ecosystems and drive up management costs. Pests and pathogens of crops, livestock and trees destroy them outright, or reduce yields and increase pest control costs. The discharge of ballast water introduces harmful aquatic organisms, including diseases, bacteria and viruses, to both marine and freshwater ecosystems, thereby degrading commercially important fisheries and recreational opportunities. And recently-spread pathogens continue to kill or disable millions of people each year, with profound social and economic implications. While considerable uncertainty remains about the total economic costs of invasions, estimates of the economic costs of particular invasives to particular sectors indicate the seriousness of the problem. Some of these, drawn primarily from Perrings *et al*., 2000, have been collected in Table 1 below. Many of these estimates remain controversial among economists.

Globalization is bringing with it a series of new medical threats, many of which can be considered a sub-set of the IAS problem. Viruses are a particular problem because they are so difficult to combat; while vaccines for viruses such as smallpox, polio, and yellow fever have proven effective, cures remain elusive and even very substantial investments to find a cure for AIDS have thus far proven only marginally effective. Even worse, the global changes that are affecting many parts of the world are expected to lead to the expansion of the ranges of many viruses that are potentially dangerous to humans. When people invade formerly unoccupied wilderness areas, this brings them into contact with a wider range of viruses and bacteria, while air travel carries them around the globe before the symptoms become apparent.

Infectious disease agents often, and perhaps typically, are invasive alien species (Delfino and Simmons, 2000). Unfamiliar types of infectious agents, either acquired by humans from domesticated or other animals, or imported inadvertently by travellers, can have devastating impacts on human populations. Pathogens can also undermine local food and livestock production, thereby causing hunger and famine. Examples:

- The bubonic plague (caused by *Pasturella pestis*) spread from central Asia through north Africa, Europe, and China using a flea vector on an invasive species of rat (*Rattus rattus*) that came originally from India.

Table 1 Indicative costs of some invasive alien species (costs in US$).

Species	Economic Variable	Economic Impact	Reference
Introduced disease organisms	Annual cost to human, plant, animal health in USA	$41 billion per year	Daszak *et al*., 2000
A sample of alien species of plants and animals	Economic costs of damage in USA	$137 billion per year	Pimentel *et al*., 2000
Salt Cedar (*Tamarix*)	Value of ecosystem services lost in western USA	$7–16 billion over 55 years	Zavaleta, 2000
Knapweed (*Centaurea* spp.) and leafy spurge (*Euphorbia escula*)	Impact on economy in three US states	$40.5 million per year direct costs $89 million indirect	Bangsund, 1999; Hirsch and Leitch, 1996
Zebra mussels (*Driessana polymorpha*)	Damages to US and European industrial plants	Cumulative costs 1989–2000 = $750 million to 1 billion	National Aquatic Nuisances Clearinghouse, 2000
Most serious invasive alien plant species	Costs 1983–92 of herbicide control in Britain	$344 million/year for 12 species	Williamson, 1998
Six weed species	Costs in Australian agroecosystems	$105 million/year	CSIRO 1997 cited in Watkinson, Freckleton and Dowling, 2000
Pinus, Hakea, Acacia, and lowland acacias	Costs on South African fynbos to restore pristine conditions	$2 billion	Turpie and Heydenrych, 2000
Water hyacinth (*Eichornia crassipes*)	Costs in 7 African countries	$20-50 million/year	Joffe-Cook, 1997, cited in Kasulo, 2000
Rabbits (*Oryctolagus*)	Costs in Australia	$373 million/year (agricultural)	Wilson, 1995, cited in White & Newton-Cross, 2000
Varroa mite	Economic cost to beekeeping in New Zealand	$267-602 million	GISP, 2001
Golden apple snail (*Pomacea canaliculata*)	Impact on rice in the Philippines	$28-45 million per year	Naylor, 1996

- The viruses carrying smallpox and measles spread from Europe into the western hemisphere shortly following European colonization. The low resistance of the indigenous peoples to these diseases helped bring down the mighty Aztec and Inca empires.
- The Irish potato famine in the 1840s was caused by a fungus (*Phytophtora infestans*) introduced from North America that attacked potatoes, with devastating impacts on the health of local people.
- The influenza A virus has its origins in birds but multiplies through domestic pigs which can be infected by multiple strains of avian influenza virus and then act as genetic "mixing vessels" that yield new recombinant-DNA viral strains. These strains can then infect the pig-tending humans, who then infect other humans, especially through rapid air transport.

At least some invasive species of plants may themselves be considered as a health hazard in both temperate and tropical regions. Binggeli (this volume) reports that large quantities of airborne pollen of *Casuarina equisetifolia* cause respiratory irritations. In the close vicinity of habitations, both *Schinus terebinthifolius* and *Melaleuca quinquenervia* appear to cause respiratory difficulties in many people, and skin contact with leaves and the sap of *S. terebinthifolius* results in red, itching rashes.

The dynamism among invasive pathogens, human behaviour, and economic development are complex and depend on interactions between the virulence of the disease, infected and susceptible populations, the pattern of human settlements, and their level of development. Large development projects, such as dams, irrigation schemes, land reclamation, road construction and population resettlement programmes, have contributed to the invasion of diseases such as malaria, dengue, schistosomiasis and trypanosomiasis. The clearing of forests in tropical regions to extend agricultural land has opened up new possibilities for wider transmission of viruses that carry haemorrhagic fevers that previously circulated benignly in wild animal hosts. Invasive species combined with variations in inter-annual rainfall, temperature, human population density, population mobility and pesticide use all contribute to one of the most profound human dimensions of invasive species: the threat to human health.

Components of biological diversity that are threatened or lost as a result of IAS can lead to the loss of traditional knowledge, innovations and practices. Likewise, customary uses of biological resources in accordance with traditional cultural practices may be inhibited or, in the worst case, discontinued completely. As intimate users of local biological resources, indigenous and local communities potentially are best-qualified to monitor the impacts of alien species on local ecosystems and their components (Article 7 of the Convention on Biological Diversity), to identify when those species become invasive, and to be involved in eradication and mitigation programmes (Article 8h of the CBD). But this depends on awareness of the problem. In China, Vietnam, Malaysia, Thailand, Korea, and Cambodia (at least), people "make merit" by releasing captive animals, especially birds, fish, and turtles; but one study in Taiwan found that 6% of birds released were exotic, and most of the fish and turtles were captive-bred exotic species that could become invasive (Severinghaus and Chi, 1999). Clearly, the cultural process of "making merit" does not intentionally include deleterious impacts on native ecosystems, but occurs largely because the people involved have no concept of IAS.

Human dimensions of the response to IAS

This book says relatively little about the actual management of IAS, leaving that important topic in the hands of other contributors to GISP (GISP, 2000). But generally speaking, GISP advocates four main management approaches: first, subject all alien species proposed for introduction to expert consideration, following the precautionary principle; second, improve the scientific basis for predicting which species proposed for deliberate introduction are likely to become invasive and which are likely to be beneficial; third, improve control of pathways for unplanned introductions (through ballast water, international trade, wooden packing material, and so forth); and fourth, improve management techniques to eradicate or control invasive alien species once prevention has failed or become impractical.

Human societies seem to have a great capacity for contradiction, with quarantine inspections, for example, being the responsibility of the same governments that promote globalization that undermines government capacity to apply effective quarantine measures (Low, this volume). Governments have a responsibility to provide regulations in the public interest, but current economic orthodoxy argues that global trade is fostered through removing regulations that may constrain such trade, such as restrictions that may prevent the introduction of a potentially invasive alien species. These contradictions help to underline the conflict of

interests between global trade and the control of IAS, and the challenges to current management measures and legal frameworks.

The human dimension is the most unpredictable variable in any management programme to control IAS. Reaser (this volume) and Mack (this volume) go into considerable detail about the psychological factors motivating people to import or use alien species that sometimes become invasive, and show how a more thorough understanding of these psychological factors can slow further invasions and promote the control of the existing ones. They demonstrate that IAS are a by-product of human values, decisions, and behaviours, suggesting that a focus on human beliefs and resultant behaviour might be more effective than focusing primarily on IAS themselves as the problem. Resource managers must therefore generate public support and understanding for any control programme before a project begins. Thus, "social embedding" of management actions, as through the "Working for Water Programme" in South Africa (Noemdoe, this volume), can foster effective management intervention.

Economic arguments have much to contribute to programmes that address the problems of IAS (Perrings *et al*., 2000). Decision-makers often find arguments couched in economic terms to be more convincing than those cast in emotive or ethical terms, and economics-based arguments of costs and benefits can be used to support stronger programmes to deal with invasive species.

But while it is important to identify costs and benefits of IAS, such determination does not automatically determine a decision because politically-charged value judgements and issues about distribution of benefits are nearly always involved. Further, the magnitude of the costs may sometimes be so high as to render an action politically unacceptable, even when the benefits are likely to be even greater; part of the problem is that the benefits may be widely spread throughout the public over a period of many years, while the costs of control may need to be paid rather quickly by taxpayers. It appears that conflicts of interest between various sectors of society regarding the costs and benefits of IAS are an inevitable fact of modern life. Such conflicts might be mediated through a more thorough identification of the full costs of the IAS. However, the value of an alien species to any particular interest group may change over time, complicating the determination of costs and benefits.

The distribution of costs and benefits is often more important than their absolute magnitude. A good illustration of the issue is the Nile perch (*Lates niloticus*). Introduced into Lake Victoria for economic reasons, it has led to the extinction of dozens, perhaps hundreds, of species of cichlid fish endemic to the lake, and has led to deforestation around the lake because firewood is needed to dry the oily perch; forest clearing in turn is leading to siltation and eutrophication, thus adding additional pressure to the continued productivity of the lake (which is also infested with invasive water hyacinth). While the Nile perch fishery in Lake Victoria generates up to US$400 million per year in export income, relatively few people living around the lake earn these economic benefits. Tons of perch end up on the plates of European diners, while protein malnutrition is a major problem around the lake (WRI, 2000). Great economic benefits are flowing to a few people from this IAS, but none of the money is being spent on managing the considerable economic and ecological costs imposed on the poor, or on the Lake Victoria ecosystem. The economics of the marketplace have proven more powerful than the ethics of equitable distribution of benefits.

Cultural factors also affect the perceptions different people have of the benefits and costs of IAS. Luken and Thieret (1996), for example, report that within less than a century after the deliberate introduction of Amur honeysuckle (*Lonicera maackii*) into North America to improve habitat for birds, serve ornamental functions in landscape plantings, and stabilize and reclaim soil, the shrub had become established in at least 24 states in the eastern USA. While many resource managers perceive the plant as an undesirable element, gardeners and horticulturalists consider it useful. Similarly, fishermen value the cultural importance of alien species of trout (*Oncorhynchus spp., Salmo spp.*) in the Sierra Nevada Mountains of the

American West, despite the powerful negative impact they have on native frog species. And St. John's Wort (*Hypericum perforatum*), which is a noxious weed with harmful effects on livestock in North America, is also gaining popularity in the natural pharmaceutical trade as an anti-depressant and is being grown legally as an agricultural crop in northwest USA (Reichard, this volume). Thus the "noxious invasive" of one cultural group is the "desirable addition" of other groups.

The perception that local people have of introduced species may be different from that of conservationists, affecting how they respond. For example, in recent years, the people living on Pitcairn Island – descendants of the *Bounty's* mutineers – have not considered *Lantana camara* as a major weed, as conservationists have done, but believe the shrub to be a soil improver. On the other hand, they view the tree *Syzygium jambos* as a major pest, not because of its impact on the native flora and fauna, but rather because of its heavy shading and its spreading, shallow and dense rooting system which renders cultivation of gardens an arduous task. Thus the weed status of a species relates to the way it interferes with day to day activities and will change through time as a society develops (Binggeli, this volume).

The words that people use to articulate their concepts and values are often taken for granted, but their linguistic framework contains many assumptions, unarticulated values, implications and consequences that need to be critically scrutinized if people are to be effective in airing their concerns about IAS (Hattingh, this volume). The vocabulary used to describe IAS often implies conceptual oppositions, such as native-alien, pure-contaminated, harmless-harmful, original-degraded, and diversity-homogeneity. Ideals like ecological integrity and authenticity associated with the values implied by such oppositions are undermined by the modern forces of globalization, which use an even more powerful set of oppositions, such as wealth-poverty, freedom-constraint, private-public, and connected-disconnected. Because globalization tends to promote homogenization, Hattingh argues that it is unable to provide a sufficiently strong conceptual framework that can incorporate the basic concepts that are required to respond to the problem of IAS, like uniqueness, ecological integrity and biological diversity.

Some methods of controlling IAS may carry health hazards as well. For example, pesticides can have serious effects on both people and ecosystems. Between 1975 and 1985, forests in Atlantic Canada were sprayed with the insecticide Matacil to control spruce budworm (*Choristoneura fumiferana*). In the late 1990s, fisheries and environmental scientists inferred that the declines in the Atlantic salmon (*Salmo salar*) stocks in the Restigouche River that occurred at that time were related to the exposures of the smolt to nonylphenol used as an inert solvent in the pesticide (Fairchild *et al*., 1999).

Recognizing the problem of IAS also forces people to face a host of losses, which can be psychologically costly. For people who value a sense of place, perhaps developed in a very deep way as children, learning that invasives have become part of "their" ecosystem can be a painful psychic blow. IAS raise the spectre that:

- What we see is not what we thought it was, i.e., "natural" or wilderness;
- What we love is not deserving, i.e., it's a foreign "weed";
- What we have protected is still at risk, i.e., almost every protected area for which we've worked so hard to create; and
- We must struggle with more complicated tradeoffs than we'd hoped, i.e., when are pesticides a necessary evil? (Windle, pers. comm.).

Once public enthusiasm to control IAS has been generated, it must be channelled in the right direction. For example, gorse (*Ulex europeus*) has become invasive in montane grasslands of Sri Lanka following its introduction about 150 years ago. Recently, several local NGOs have launched volunteer programmes to remove gorse. However, some species of endemic reptiles and amphibians have found gorse a congenial habitat, providing food and cover. When the eradication programmes removed this habitat virtually overnight, the endemic species were

exposed to native opportunistic predators such as crows (Marambe *et al*., this volume). Therefore, programmes to eradicate invasive species of plant also need to consider restoring the ecological functions of the species that are removed.

Over 40 international conventions, agreements, and guidelines have been enacted for addressing the problem of IAS, at least in part, and many more are being prepared (Shine *et al*., 2000). Governments have expressed their concerns about the problem of IAS especially through the Convention on Biological Diversity (CBD), which calls on the Parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats, or species" (Article 8h). But the expanding impact of IAS on both global economies and the environment implies that these international instruments have been insufficient to prevent and combat IAS effectively, suggesting that additional measures, such as a protocol under the CBD, are advisable.

At the national level, those opposed to eradicating IAS on ethical grounds often are prepared to argue their case in court, where litigation can be effective. This challenge calls for a legal framework that clearly recognizes the need to eradicate IAS when they threaten the greater public good, and education for judges to ensure that they understand the issues before them. National and even local legislation also needs to recognize the kinds of human dimensions that are identified in this book, including such elements as ethical concerns, human health, trade, cultural considerations, and even international obligations. Human dimensions are an essential element in trying to determine what existing regulatory, financial, and penal disincentives could be adjusted to deter trade and transport activities that carry high risks, and to determine the specific levels of disincentives that will deter invasives (Jenkins, this volume). New Zealand perhaps has the most comprehensive modern legislation, as its Biosecurity Act of 1993 has led to a strategic approach at the sub-national level, involving both invasive species and genetically modified organisms (Warren, this volume; Veitch and Clout, this volume).

Political support is clearly essential to implement coherent policies, laws, and regulations to address the problem of IAS. This depends in turn on support of the public, which ultimately depends on the quality of information that is provided on the issue and the effectiveness with which such information is transmitted. Advocates need to convince the general public that controlling an invasive species is worthwhile. For example, the programme in New Zealand to control brush-tailed possum (*Trichosurus vulpecula*) was called "Operation ForestSave" and the promotional information showed lovely flowering native trees, without a cute furry possum in sight. In Europe, the issue is presented as "Save the Red Squirrels", not "Kill the Grey Squirrels". And in Queensland, Australia, the endangered cassowary (*Casuarius casuarius*) is used as the "front" for controlling feral pigs, fully involving community groups in the programme (Low, this volume).

The US National Park Service has encountered considerable public resistance to efforts to eradicate wild burros (*Equus asinus*) from the Mojave National Reserve, mountain goats (*Oreamnos americanus*) from Olympic National Park, and sheep (*Ovis aries*) from Santa Cruz Island. At least part of this resistance arises because these IAS are large mammals that some interest groups find attractive, but the negative ecological and economic impact of these species could be used to influence the political process. For example, heavy grazing on the native vegetation by feral populations of horses and donkeys allows non-native annuals to displace native perennials, and costs the nation an estimated $5 million per year in forage losses, implying that these species eat forage worth US$100 per animal per year. They also diminish the primary food sources of native bighorn sheep (*Ovis canadensis*) and seed-eating birds, reducing the abundance of these natives (Pimentel *et al*., 2000). By making people aware of the ecological and economic impact of the invasive large grazers, public attitudes to control operations may be changed.

Hattingh (this volume) argues that ecological communities are delineated by people, who draw the lines that distinguish between that which is "native" and that which is "alien". These

lines are established by the way people perceive such distinctions and communicate these perceptions through narratives or stories that they tell to represent reality. Philosophers argue that these distinctions exist only insofar as people continue telling these stories. Biologists respond that a species introduced by people on a continent different from where it lives is self-evidently non-native. The three-tiered policy response developed by GISP to deal with the problem of IAS, involving prevention, eradication, and management if the first two do not succeed, depends on these narratives that people have developed about what is native and what is alien, involving value-laden conceptual distinctions. Perhaps the challenge of addressing IAS will raise fundamental questions about the extent to which we define our humanity by our relation to the rest of nature.

Different interest groups may have different ethical positions. At least some animal rights groups, for example, argue that the intrinsic right to exist rests at the level of individual animals, not only of the species as a whole, and therefore strongly resist any measures to control them, much less eradicate entire populations even if they are IAS (though few extend this to pathogenic micro-organisms, or even insects). Animal rights advocates contend that nature will find its own solution to the new situation, and that any human intervention is immoral because we have no right to select one species or individual over another (though of course we do so when introducing an alien species into a new habitat). Public acceptance can be significantly influenced by animal rights groups, whose views must be carefully considered when assessing the feasibility of eradicating an invasive species. Unfortunately, their ethical concerns cannot be answered by scientific evidence of conservation threats, or even by economic arguments.

Some widely-held ethical values have unrecognized ramifications for IAS. For example, our world has become increasingly interconnected over both time and space, where individuals have come to expect great freedom of individual behaviour (Low, this volume). But their behaviour when introducing alien species has significant, though undefined, influences on many other people, most of whom are unknown to those who are affecting that behaviour. Ethics of obligations and responsibilities are not always easily understood against the backdrop of the ethic of "consumer freedom" to grow exotic plants or keep exotic pets that might escape captivity to become invasive.

Thus the invasive alien species issue can be seen as ultimately an ethical concern. If people are seeking to maximize their material welfare, or even the diversity of species with which they surround themselves, alien species might well be a part of their rational response. But when alien species become invasive, destabilizing ecosystems and reducing diversity, then control is a far more acceptable, even necessary, response. Since invasions invariably involve trade-offs, the determination of costs and benefits of IAS becomes paramount (though this too has its ethical components).

One useful way of building political support is through scenario planning, a way of developing stories of the future that are plausible and meaningful to the intended audience. By considering plausible futures based on options that are available to decision makers, scenarios can provide a means for politicians and other decision makers to deal with the inherent uncertainty of the invasive species problem (see Chapman *et al*., this volume, for a more thorough discussion of this point). Scenario planning also enables planners to go beyond modelling and biological factors to take into account the extraordinary complexity of human enterprises and human-dominated systems. Scenarios focus on highlighting and understanding the effects of the large-scale forces that push the future in different directions rather than the details of that future.

Thus the concept of invasive alien species is not purely dependent upon objective ecological criteria, but also on human concepts used to identify origin, authenticity, and responsibility. As Hattingh (this volume) advocates, we need an ethics of conceptual responsibility to become more aware of the dominant lines of argument we use in our debates about IAS, including the manner in which they function, their history, the mechanisms through which these views have

been established as authoritative and through which they have become institutionalised, and their practical policy and political consequences. He also suggests that we need to be open to alternative narratives that might be more effective in articulating concerns about IAS to policy-makers, and to the general public.

Conclusions

IAS are able to invade new habitats and constantly extend their distribution, thereby representing a threat to native species, human health, or other economic or social interests. One remarkable human dimension is the fact that a strong consensus can be built that many specific invasions are harmful, including killer bees, water hyacinth, kudzu, spruce budworms, various pathogens, and agricultural weeds. The issue of IAS, therefore, can bring together interest groups that might otherwise be in opposition, such as farmers and conservation groups. Bringing in the human dimensions can shift the focus from the IAS itself to the human actions that facilitate its spread or manage its control, and implies that focussing directly on the invasive species is likely to provide only symptomatic relief. A more fundamental solution requires addressing the ultimate human causes of the problem, often the economic motivations that drive or enable species introductions.

This introductory chapter has identified some of the human dimensions involved in IAS. It is apparent that these dimensions are interconnected, and are relevant in different degrees in different countries, or with different species of invasives. But the presence of so many human dimensions implies that approaches to management need to involve many sectors of modern society, including trade, tourism, industry, the military, public health, and so forth. Addressing the problem will call for more collaboration between ecologists, geographers, land use planners, economists, sociologists, psychologists and others to investigate the human dimensions of biological invasions.

The complex relationship between globalization and invasion pathways is perhaps the most important human dimension of IAS, and should be occupying the minds of policy makers in the next few decades (Carleton and Ruiz, forthcoming). Globalization carries with it the rise of transnational corporations, international financing, and multi-media marketing that undermine the political power of most governments, weakening their ability to regulate economic behaviour in the public benefit (Hattingh, this volume). One important implication is that concern about IAS needs to be expressed in terms of the threats to the resource base of the global economic system, which translates into monetary figures. Thus many of those who are concerned about the problems of IAS have quite properly turned to economics to argue their case.

Humans, with all their diversity of quirks, strengths, and weaknesses, are at the heart of the problem of IAS and, paradoxically, also at the heart of the solution. Given the ultimate human motivations of survival, reproduction, and perhaps spiritual fulfilment, and the more immediate economic motivations, people might be encouraged to contribute to addressing the problem of IAS by such measures as:

- Helping the public to identify and embrace values that have a direct relationship to basic needs and are environmentally sound, thereby also achieving longer term benefits. This might include promoting the concept of “community”, including native species, as a value that can balance the powerful economic values of globalized trade.
- Developing conservation practices and ethics that emphasise the importance of natural ecosystems, for example by refining distinctions between natural and anthropogenic conditions, devising ways to use ecosystems without losing biotic diversity, and facilitating shifts in societal values toward more respect for nature.

- Identifying measures that work within existing value systems, but encourage people to support conservation measures (for example, through the use of economic incentives and disincentives).
- Ensuring that the costs of controlling IAS are "internalized", paid by those who are benefiting from intentional introduction and those responsible for unintentional introductions.
- Linking the concern about invasive alien species to the drive for development that motivates most people, and virtually all governments, today.
- Including human dimensions in the various conventions, agreements, and guidelines on IAS, such as those developed under the Convention on Biological Diversity.
- When introducing new species, use risk assessment procedures that take into account future changes in usage and demonstrate that – to the best of current knowledge – detrimental impacts will be limited.

Many of the chapters in this book have identified a fundamental constraint against changing the way people behave in regard to IAS: few people in any part of the world consciously perceive that they have been affected negatively by IAS, either directly or indirectly. While the Global Invasive Species Programme has been reasonably successful in developing technical information for resource managers, the supply of information on IAS to the general public remains generally poor, so that most people have little idea of which species are invasive, what are their impacts, and what are appropriate control methods. In the absence of such information, inappropriate responses can be expected. On the other hand, human perceptions are filtered by the media, the availability of information, and language, and all of these can be influenced to limit the spread of IAS.

It is remarkable that some agencies that should know better are actually promoting IAS in the name of development. For example, development assistance agencies often seem to prefer to introduce alien species (especially from the country providing the funding for the assistance), rather than promoting native species. Even UN agencies, such as FAO, are widely promoting numerous weedy trees, shrubs, fodder grasses and legumes that are known to be highly invasive in at least some countries.

Others are guilty of lack of involvement in the issue. For example, if the problems of IAS are to be addressed successfully, more conservation organizations will need to become more actively involved. Perhaps they have avoided doing so because advocating the eradication of some animals or plants might confuse at least some of their supporters among the general public, especially those who equate conservation with animal rights. This is a serious problem with cute furry animals such as the invasive American grey squirrel (*Sciurus carolinensis*) in Italy, especially when the Italian press refers to them as "Chip and Dale" after the Walt Disney cartoon characters (ironically using non-native icons to refer to a problem of non-natives). In any case, conservation organizations should give this issue much higher priority.

Their support needs to be based on a stronger foundation of science. Despite decades of research, scientific knowledge of the biology, ecology, and human dimensions of invasive alien species remains very incomplete. With no more than 20% of the world's species even scientifically described, scientists simply are unable to predict which species are likely to become invasive or to assess the precise ecological, social or economic impact they are likely to have. With such incomplete knowledge, we risk unexpected consequences any time a new species is introduced into an ecosystem. Unpredicted effects, such as the hole in the ozone layer, global warming, mad cow disease, pesticide accumulation, the impacts of hormones in the environment, and so forth, can result from seemingly beneficial products and procedures. It therefore seems sensible to do everything we can to ensure that we err on the side of precaution, perhaps on occasion sacrificing some economic profit for the businesses directly involved while helping to ensure a healthier future for all of society. Thus we should also strongly

support research to assess the risks of invasive alien species and to find effective means of dealing with the risks.

Research priorities for human dimensions of IAS include:

- Identifying conflicting interests regarding benefits and risks of introductions, substantiating evaluations of those benefits and risks, and determining the likely distribution of benefits and risks among sectors of society (Ewel *et al*., 1999).
- Identifying underlying causes for human choice in relation to IAS, including identifying how human beliefs about specific invasive species influence their actions to promote or limit the spread of that species.
- Ascertaining what is known scientifically about the ubiquitous human affinity for other species. Is "biophilia" an innate behaviour? Is it a conditioned response? Does it lead to more alien species being imported? Can the human behaviour that stems from this attraction to other species be modified and redirected? If so, how?
- Evaluating potentially useful indigenous organisms rather than non-indigenous ones, thereby reducing incentives for introductions.
- Elucidating the interactions between the media, the public, and scientists/ conservationists.
- Identifying the views of indigenous peoples and other interest groups about invasive alien species.
- Carrying out a predictive modelling exercise to project what might be the outcome if we are unable to slow or stop the spread of IAS.

This book has sought to elucidate basic economic, social, psychological, ethical, and political elements about IAS, but the challenge has been considerable and it appears that each case needs to be considered on its own merits. That said, here are some human dimensions elements to consider in addressing any IAS problem:

- Ensure that those who are most directly affected by the IAS are involved in decisions about how to manage the problem.
- Build sufficient public information programmes into each effort, investing more in this regard where the problem is likely to involve controversial techniques (such as use of poisons).
- Conduct a detailed analysis of human dimensions as these affect the interested parties, including the general public and decision makers.
- Build linkages between the management of IAS and development, through involving economic sectors such as health, energy, agriculture (food security), forestry, and fisheries.
- Establish general principles for guiding policies that explicitly promote the identities and values that motivate and direct people to minimize the spread of IAS.

Gould (1998) argues that the preference for native species provides "the only sure protection against our profound ignorance of consequences when we import exotics", because we can never be certain about the behaviour of an alien species imported into a new environment. Thus we should do everything possible to prevent unwanted invasions, carry out careful assessments before intentionally introducing an alien species into a new environment, build a stronger awareness among the general public about the problems of IAS, mobilize conservation organizations to address the problems, and build an ethic of responsibility among those most directly involved in the problem. The global trading system brings many benefits but it needs to be managed in a way that minimizes any deleterious impacts of invasive alien species on ecosystems, human health, and economic interests. Human dimensions are central in doing so.

Human Perceptions

Motivations and consequences of the human dispersal of plants

Richard N. Mack

Abstract

In attempting to colonize new areas, humans proceed in a deliberate manner that arises from deep-seated motives based on a compelling need for security. Aside from immediate concerns about personal safety, humans strive for security in the amount, reliability, and sustainability of their food, fuel, forage, and medicine. Historic trans-oceanic voyages of colonization epitomize the preparation to meet these concerns because return to, or even timely resupply from, the homeland was problematical. As a result, colonists bound for distant locales have always carried living plants. Further incentive for immigrants to transport plants arises from the need for plants that are not only reliable but also familiar. Adoption of newly encountered plants, especially as food or medicine, proceeds reluctantly and often through dire necessity. Familiar food also serves as a tangible reminder of the homeland, thereby contributing to a sense of security. Perception among immigrants that the homeland remains a source of solutions is also common. Even centuries after the initial immigrants arrived, their descendants readily import plants as solutions to perceived deficiencies or newly detected problems in their colonized land. All people share a common allure for diversity in their surroundings, including the diversity provided by ornamental plants. This incentive or preference for floristic diversity in people's immediate vicinity has long driven the enormous effort to gather species from afar. The composite consequence of these expressions of human necessity and choice has been the dispersal of tens of thousands of species into distant new ranges. Some species transported as the result of these expressions of human behaviour have become invasive; the number of such species belies their immense environmental and economic impact. In effect, deep-seated aspects of human behavior continue to determine the character, extent, and rate of the human-mediated transformation of the earth's vegetation.

Introduction

Even if humans were not anthropocentric, human behaviour would be a worthy subject for study. We are, after all, members of a fascinating species. Among aspects of our behaviour, we express strong motives or motivations (*sensu* Mook, 1987) for which the evolutionary explanations seem apparent. For example, the motivations to attain personal security, including a secure supply of food and shelter, protection from hazards, and avoidance of disease, all relate directly to reproductive fitness (Ridley, 1993). The means by which people in any culture attempt to attain this security is rapidly taught and learned within that group (Ornstein, 1985).

We also display other strong behaviours that do not necessarily enhance fitness but certainly contribute to our perception of well being. These behaviours include our extraordinarily varied

preferences for food, which contribute both to our sense of security as well as satisfaction or pleasure (Wardlaw, 1999; Rozin, 2000). Furthermore, we actively select, acquire or modify our surroundings to achieve an environment that we find pleasing or at least not unpleasing; much of this behaviour is also learned or instilled from our living groups (Brown, 1999). One potential common intercultural thread, however, is the desire for variation itself, e.g., paintings whether created by an English landscape artist or an Australian aborigine inspire us in part through the highly selective use of color, texture and form.

I have elsewhere referred to these motivations as primal urges (Mack, 1999). Psychologists may be reluctant to employ "primal" as it may imply "innate" and avoid referring to "urges" altogether (F. McSweeney, pers. comm). I simply mean that we are influenced strongly by some basal, i.e., "primal" motivations. I further contend that these motives or primal urges are central to explanations for humans' deliberate geographic movement of plants. The number of species transported and the sheer magnitude of this traffic has grown meteorically in the last 500 years (di Castri, 1989; Mack, 1999). The initiating events for this plant dispersal worldwide have been the travels of humans, first as explorers, but soon thereafter as colonists to new areas of habitation, even though they were often not the first humans to colonize the locale. I will not address the underlying causes for this exploration and human colonization, although the pursuit of broad-sense security, including the acquisition of wealth, likely has been a strong component. Instead I explore here the specific motivations for moving plants and in turn the unintended consequences of some of this global plant dispersal – thousands of plant naturalizations (Rejmanek and Randall, 1994) and a significant number of plant invasions (*sensu* Mack *et al.,* 2000).

The likelihood of dispersal varies greatly among species. Without human involvement, the dispersal of any plant disseminule to a specific location is simultaneously dependent on multiple low probabilities, including the appearance of a suitable vector or currents or tides coinciding with the maturation of disseminules (Ridley, 1930). Humans have substantially raised these long odds through our ability to move plants over great distances. As a result, we have in less than 500 years caused enormous transformations of the vegetative cover across the earth (Meyer and Turner, 1994); these transformations are not confined to the proliferation of cultivated fields. Many deliberately introduced species have spread and detrimentally affected their new environments in unanticipated ways (Humphries *et al.,* 1991; Vitousek *et al.,* 1996). Over half the recently naturalized species in Australia arrived as deliberate introductions (Groves, 1998); well over half the naturalized species in environmentally distinct regions of the United States have a similar origin (Mack and Erneberg, unpublished data). Most naturalized floras worldwide were likely assembled in the same manner.

Understanding the motivations that have guided this wholesale upheaval of the earth's flora may well serve as a guide to the character, directions, and consequences of future plant dispersal and subsequent naturalizations. With prediction comes the knowledge to maximize the benefits of this plant dispersal, while minimizing its risks (Anon., 1997; Pheloung, 1999). The motives that shape our plant choices for dispersal of the world's flora, the locales of these plants' delivery, and the sometimes-disastrous environmental and economic consequences of these choices form the subjects of this chapter.

The first motive: a secure food source

Abundant, reliable, and timely access to an array of plant species fosters a sense of security in general, but it is most apparent in the nexus between a food source and personal security. Almost all societies are dependent on routine plant consumption, which forms the bulk of their caloric and nutritive intake (Lowenberg *et al.,* 1974; Lyman, 1989). As a result, a secure food source assumes primacy in the preparation among any immigrants who envision colonizing a new region that is far removed from their homeland. Such groups must either have absolute

assurance of the availability of food upon arrival or carry with them the germplasm and cultivation technology necessary to establish a food supply (Mack, 1999). None would be so reckless as to gamble their lives and the lives of their descendants on the off chance that ample food would be available in a new range once they have lost reliable contact with their homeland.

The universal importance among colonists to secure a reliable food source, as well as secure sources of fuel, fiber, and medicine, is abundantly demonstrated by the preparations that immigrants world-wide have made for a voyage of colonization (Mack, 1999). Ancestors of the indigenous Hawaiians introduced as many as 32 species to the Hawaiian flora, most were essential as food. Their aforethought was prudent: it is doubtful the Hawaiian flora before their arrival contained species that would have substituted nutritionally or as reliably for their introductions: banana, breadfruit, coconut, sugarcane, taro, yam, kukui (*Aleurites moluccana* now *Paraserianthus falcataria*), wauke (*Brussonetia paprifera*) (Nagata, 1985). Many, if not all, of these Polynesian introductions have become naturalized (Wagner *et al.,* 1990).

Early European colonists to the Western Hemisphere were also meticulous to ensure that their plant needs would be satisfied. Columbus's second voyage to the Western Hemisphere was motivated by aspirations of colonization as well as exploration, and his ship manifests list the seeds or vegetative cuttings of such staple European crops as chickpeas, stone fruit species, grapes, melons, onions, radishes, sugar cane, and wheat. Even prior knowledge that native Americans obviously met their needs from the native biota was insufficient assurance for Columbus to leave his colonists to fend for themselves. (His colony, Navidad, was nevertheless doomed) (Crosby, 1972). So extreme was the need among early would-be European colonials for an assured food supply that explorers even experimented with cultivated crops before any colonists arrived. In 1542 Cartier directed that wheat be sown near present-day Montreal, decades before a colony was established. In 1602, Gosnold landed on Cuttyhunk Island (present-day Massachusetts) and reported that, "in mid-May we did sowe in this Island (as for a triall) in sundry places, Wheat, Barley, Oates, and Pease, which in foureteene daies were sprung up nine inches and more … " (Rea, 1974). Here again, these crop "trialls" were conducted almost two decades before the first European colonists (the English Pilgrims) arrived in the region.

Highly domesticated crop plants usually lack the ability to become invasive: they are often sterile, may require hand pollination, or survive outside their native range only through intensive cultivation (Simmonds, 1979). Nevertheless, even such domesticated crops as barley, oats, rice, bananas, coconuts, and breadfruit are either naturalized or have persistent land races in many new ranges (Harlan, 1975). The deep-seated motivation among colonists worldwide to secure this most basic of needs provided by plants has expanded the naturalized ranges of some crops (Harlan, 1975; Mack, 1999).

Fear of newly encountered plants as food

Humans' motive or primal urge for a secure food supply is complicated by food preferences. As youth we learn through social transmission, as well as some trial and error, about which plants to avoid because they are coincident with the onset of illness and which foods satisfy universal preferences for sweetness and saltiness (Rozin, 2000). Humans also make food choices to invoke pleasure and instill reassurance. These food preferences are substantially sharpened through cultural interactions (Capaldi, 1996; Rozin, 2000). Probably all travelers have occasionally sought out "home cooking", i.e., food with which they were most familiar. Such food is not only deemed safe (i.e., not likely to cause illness in an otherwise uncertain environment) but also invokes memories of the safety and security of home (Capaldi, 1996).

Seeking familiar food is coupled with the universal human reluctance to sample novel foods, even food eaten routinely by other people (Lowenberg *et al.,* 1974; Lyman, 1989). Eventual

acceptance of a food may result from repeated contact, i.e., formerly novel food becomes acceptable by repeated contact alone (Capaldi, 1996; Rozin, 2000). Among immigrants, conditions of extreme food deprivation force such familiarity; initial reluctance is overturned by the desire for self-preservation. European immigrants in the Western Hemisphere were reluctant to adopt the white potato as food (Crosby, 1972), although eventually they and many native Europeans, most conspicuously the Irish, clearly adopted the potato to the point that it became a staple food (Speed, 1976). European colonists in 16th century Mesoamerica initially preferred wheat to maize, but maize along with manioc became acceptable when neither a reliable local nor a foreign source of wheat emerged (Crosby, 1972). As a cultural result, the descendants of early immigrants to Brazil today readily include both maize and manioc in their diet.

Each ethnic group of immigrants brings familiar edible plants, including seasonings, to a new homeland. For example, Europeans from the Mediterranean Basin have introduced olives, garlic, and fennel, wherever they have settled. One of these plant immigrants, olives, has become invasive in South Australia; *Olea europaea* now forms a prominent new arboreal layer in eucalypt parklands (Parsons and Cuthbertson, 1992). Northern European colonists have widely introduced brassicas (cabbage, kale, rape) as well as many root crops (radishes, carrots, beets, and parsnip) (Harlan, 1975; Simmonds, 1979). Many of these edible species have become naturalized, including *Taraxacum officinale*, *Rorippa nasturtium-aquaticum,* and *Rubus* spp. (Harlan, 1975). Asian cuisines have quite different plant ingredients from those employed in Europe. As a result, Indian, Indonesian, Thai and especially Chinese immigrants have widely introduced plants they prefer to eat. Among these plant culinary immigrants are now such naturalized species as *Brassica juncea* and *Coriandrum sativum,* which despite its native European range has been adopted in Chinese cuisine (Wagner *et al.,* 1990). Unable to import a familiar edible food, immigrants may even inadvertently adopt a substitute that proves invasive. The recent Cambodian immigrants to Australia mistook the highly invasive *Alternanthera philoxeroides* (alligator weed) for a favorite aquatic plant in Cambodia (*Alternanthera sessilis*). Thus, they fostered and spread the plant in their adopted home, until the mistake was pointed out (J. Virtue, pers. comm).

Along with its traditional importance in human nutrition and animal behaviour, psychology, cultural anthropology, and sociology, food preference becomes a legitimate area of interest in invasion biology. Immigrants' cultural heritage clearly influences the plants that are introduced for food into potential new ranges (Rozin, 2000). These strong biases have repeatedly placed crops in far-flung locales where they have not only become naturalized but in some cases have also become invasive (Harlan, 1975; Mack, 1991, 1999).

The Call Home Syndrome: pleas for the essential

No colonists could predict all the crop species that would be needed in a distant locale, despite careful planning and even prior knowledge of the locale's biota and physical environment. The ability to "call home", i.e., to request essential plants from their homeland for unanticipated needs, has long characterized colonization attempts worldwide. By 1524 Cortes, writing from Mexico, was imploring the King of Spain to include essential plants within future shipments: "I have also explained to your Caesarian Majesty the need for plants of all kinds; for every species of agriculture may flourish here; but nothing has been so far provided, and I again pray your majesty to order a provision from the Casa de contracion at Seville, so that no ship be allowed to sail without bringing a certain number of plants which would favour the population and prosperity of the country" (MacNutt, 1908). He assessed that among deficiencies in the newly conquered lands were plants to treat a host of human afflictions that Spanish settlers were already encountering (Kay, 1996). These early pleas were apparently answered; Bernardo Cobo, a 17th century Spanish commentator, stated that, "All the regions of the globe have

contributed their fruits and abundance to adorn and enrich this quarter part of the world, which we Spaniards found so poor and destitute of the plants and animals most necessary to nourish and give service to mankind … " (Cobo, 1964 as cited in Crosby, 1972). Even today, non-indigenous species may total two-thirds of the most frequently used medicinal herbs in Mexico (Kay, 1996).

Such pleas for home-grown solutions are intriguing from at least two perspectives: the perceived problems often arose decades, even centuries, after the immigrants' arrival, yet the collective inclination remained strong to call for a solution from a homeland that most had never seen. Furthermore, little or no effort was usually exerted to find a local solution to a local problem. English settlers along the eastern coast of North America in the 17th century soon became dissatisfied with the quality of native forage. One 17th century settler in New England complained that the native forage " … is so devoid of nutritive vertue, that our beasts grow lousy with feeding on it, and are much out of heart and lung" (Cronon, 1983). Securing nutritious forage was a serious concern for settlers who had neither the time nor the inclination to experiment with native species as forage. By 1635 settlers to Maryland were cautioned to bring a "good store of Claver grasse seede, to make good meadow" (Edwards, 1948). The native species had been clearly determined to be unsuitable.

Requests even arose for timber species. The 17th century Dutch colonists to the Cape of Good Hope soon discovered the paucity of native woody plants, even for firewood. One extraordinary solution was the regular importation of lumber from Europe and the East Indies (Wilson and Thompson, 1969). It was nevertheless deemed necessary by the 19th century to establish a local source of lumber as well as introduce woody dune-binding plants. Some of these species subsequently became highly invasive, e.g., *Acacia longifolia, Acacia saligna, Hakea suaveolens* (Shaughnessy, 1986).

Calls home also included requests for species to solve self-inflicted environmental problems. Much American folklore to the contrary, the Intermountain West of the United States is only marginally suitable for livestock; the principal native grasses, all bunchgrasses, are intrinsically intolerant of persistent grazing (Mack and Thompson, 1982). As a result, the role of these grasses was radically reduced in less than 50 years after the wholesale introduction of cattle and sheep. By 1900 many had concluded that " … the native grass is gone, and experiment has not yet fully demonstrated the adaptability of any other grass to this soil and climate" (Anon., 1901). Little or no effort was spent exploring solutions with native species; the call went out instead for species from Eurasia. Non-indigenous grasses (e.g. *Agropyron cristatum*, *Bromus inermis*) and even the highly invasive *Bromus tectorum* were soon being evaluated as substitutes (Mack, 1981). Few species that were subsequently introduced are suitable as forage, and some could yet produce plant invasions, such as *Kochia prostrata* and *Agropyron repens* hybrids (Mack and Thompson, 1982; Mack, 1999). Tragically, the Call Home Syndrome continues. Currently much of the Intermontane West is being sown with non-indigenous species in a futile attempt to sustain livestock production (Monsen, 1990), while ostensibly controlling fires sparked by *Bromus tectorum*, now the region's most abundant plant invader (Mack, 1981).

Hawaii has long been the site of a variant of the Call Home Syndrome that has been played out with tragic consequences. Similar to many other subtropical and tropical islands that became European or American colonies, Hawaii proved ideal for the production of sugar cane (Viola and Margolis, 1991). Much of Oahu and other Hawaiian Islands was cleared of native forest and planted to sugarcane. In their zeal to maximize the acreage of sugarcane, the American planters blundered; by clear-cutting far up-slope, they destroyed the ability of the islands' mountain habitats to retain water and soil. By 1919 erosion had much increased and water supplies were simultaneously depleted among the settlements and fields down-slope. Even the water supply of Honolulu was strained by this rampant land-clearing (Lyon, 1923).

The authorities soon realized that massive reforestation was needed to replace what they termed the "decadent forests" or "decrepit forests" (Lyon, 1922; McEldowney, 1930). With little experimentation, they concluded that the native woody species, such as *Metrosideros* spp. (Ohi'a), were unsuitable in reforestation; the species either grew too slowly from cuttings or had insufficient germination rates to facilitate rapid re-establishment of the forest cover (Lyon, 1922, 1929). They soon turned to the indiscriminate importation of at least 900 non-indigenous woody species as potential remedies for the denuded landscape (Lyon, 1929). These introduced species were raised in experimental gardens, and scores of the non-indigenous species were established on the denuded mountain terrain. Much effort was clearly expended in this introduction of non-indigenous species. One group alone planted 786,320 plants (all apparently non-indigenous) on Oahu between 1921 and 1930 (McEldowney, 1930); another nursery in Honolulu distributed more than 1,250,000 plants in the same period (Lyon, 1929).

The pell-mell rush to establish rapidly growing non-indigenous species unleashed some of the most devastating plant invasions in Hawaii. Species released during this 20-year program that have become at least naturalized, if not invasive, include *Acacia confusa, Ardusia solanacea (*now *A. elliptica), Casuarina equisetifolia, Paraserianthus falcataria, Eucalytpus globulus, Eucalyptus robustus, Olea europaea, Psidium catteyanum, Terminalia myriocarpa* and *Trema orientalis* (Lyon, 1929; McEldowney, 1930; Wagner *et al.,* 1990). Fortunately, other non-indigenous species failed to become naturalized, including *Tamarix aphylla*. The foresters' knowledge of the introduced species they introduced was as meager as their knowledge of the native species. They attempted to sow seeds from airplanes (McEldowney, 1930), but few seeds survived once broadcast sown on montane slopes. Elsewhere they planted or sowed figs (e.g. *Ficus macrophylla, Ficus rubiginosa*), even going to the extraordinary step of ensuring that these figs' wasp pollinators were also introduced (McEldowney, 1930). The eventual dispersal of these figs by non-indigenous frugivorous birds, including the Mynah bird, to the most remote forests was actually considered desirable (Lyon, 1922, 1929).

The resulting sad sequence of events in Hawaii's environmental history is clear. American colonists presumptively dismissed the ability of the native flora to correct an environmental problem they themselves had caused; their ignorance of the biology of the native species joined with their motivation to seek a rapid solution from home or elsewhere. Then egregious science justified their motivation to absurd extremes that caused, in turn, the greatest period of woody species naturalizations in Hawaii's history. The consequences of these disastrously flawed policies, a landscape now largely dominated by naturalized and invasive trees, appear permanent (Cuddihy and Stone, 1990).

European and North American colonies are often not free of the well-intentioned consequences of the Call Home (or anywhere) Syndrome, even after their independence; the implementation continues of bad science laced with good intentions. Many undeveloped nations have lost much of their native forests in the last 50 years through their increasing needs for fuel, forage, and timber; the results have been massive erosion, clogged riverine ecosystems and severe threats to the conservation of their biota (Meyer and Turner, 1994). The advice from foreign advisors (mainly European and North American) has consistently been for the establishment of introduced species, at the expense of re-establishing the native arboreal vegetation (Zobel *et al.,* 1987; Hughes, 1994).

Madagascar has been a stage upon which the motives or motivations of foreign forestry advisors have been played out with tragic results. Long before French colonists arrived in Madagascar in the mid-19th century, cattle were the Malagasy people's chief source of meat. Then as now cattle also served as all-purpose currency and a standard for financial security (Sussman *et al.,* 1996), thereby invoking enormous incentive for cattle-raising beyond their value as food. Cattle require grasslands, not the forests that dominated the Madagascar's landscape before the arrival of humans 1500-2000 years ago. Since Madagascar's initial occupation by graziers, the island's forest cover has been removed, especially with rapid

population growth in the late 20th century (Sussman *et al.,* 1996). Throughout the 20th century foreign advisors have encouraged re-forestation with a wide array of non-indigenous species (Chauvet, 1968). At least 68 eucalypt species alone have been introduced (Chauvet, 1968), along with Australian acacias, European and Asian pines (e.g. *Pinus caribaea, Pinus kesiya, Pinus merkusii, Pinus patula*), and other introduced species, such as *Casuarina equisetifolia* and *Grevillea robusta* (Chauvet, 1968; Anon., 1993; P. Andriambelonoro, pers. comm.). Today the vegetation in the country's Central Highlands and eastern coastline is dominated by coppiced wood-lots of eucalypts (Mack, pers. obs.); little of the native forest remains (Jenkins, 1987; Sussman *et al.,* 1996). Reminiscent of the history of forestry in Hawaii, Madagascar's non-indigenous arboreal assembly can be traced to the primal inclination of foreign foresters to place, in effect, a long-distance call for a solution.

The Call Home Syndrome: requests for the familiar

Colonists soon display a further need to seek plants from their homeland. A sense of security may arise not only from a secure source for food and other essential commodities but also from familiar surroundings or at least surroundings that are not as alien as first encountered (Taylor, 1983). Such reminders of home take many forms; one of the most consistent among colonists has been the importation of aesthetic or ornamental plants (Brown, 1999). Need for such comfort has emerged repeatedly among colonies world-wide and appears to be strong, especially once secure sources of food, fuel, and medicine have been identified (Mack, 1991, 1999).

The need for familiar plants by colonists is even illustrated in antiquity. The Romans went to great lengths to import familiar plants from the Mediterranean Basin as they presided over their far-flung empire. They clearly felt no compunction or need to exclusively adopt local food, seasonings, drink or be restricted to native plants for shade and visual pleasure (Renfrew as cited in Brown, 1999). Pollen records from Roman ruins in Britain reveal southern European plants they grew successfully in southern Britain, including *Apium graveolens, Cannabis sativa, Ficus carica, Foeniculum vulgare, Juglans regia, Lens esculenta, Papaver somniferum, Peucedanum graveolens, Pisum sativum, Pinus pinea,* and *Prunus cerasus*. Some (e.g. *Atropa belladonna, Hyoscyamus niger, Verbena officinalis*) are now naturalized (Godwin, 1975).

Perhaps the best known colonial manifestations of this need for the familiar are the acclimatization societies that flourished in the 19th century. Most were in English-speaking colonies and former colonies, such as Australia, New Zealand and the United States (Lever, 1992). Their goal was largely to import species deemed "missing" or "lacking" in the new colony, whether the perceived need was rabbits for Australia or honeybees for New Zealand (Thomson, 1922; Lever, 1992). Most societies emphasized animal introductions, but plants were not ignored (Esler, 1987). Furthermore, their imported plants were not exclusively from homelands in Europe; any species deemed potentially beneficial was fair game for importation, including ludicrous choices. The Acclimatisation Society of Victoria, for example, recommended the importation of tussock grasses from the Falkland Islands for erosion control, buffalo grass *(Buchloe dactyloides)* from North America for forage, larches and all pines (Lever, 1992). The well-intended imports by these societies have often proven disastrous (Thompson, 1922; Esler, 1987); e.g., early support for the introduction of blackberries (*Rubus* spp., a hybridized array of taxa) into Australia can be traced to an acclimatization society (Rolls, 1969). Fortunately, most of these outlandish introductions failed to become naturalized. Nevertheless the damage caused by these societies, especially in Australia and New Zealand, lingers (Groves, 1986).

An extreme expression of the Call Home Syndrome for familiar plants occurred during the British Raj in India. India was culturally and environmentally so different from the British Isles that it is little wonder that the British colonials sought reminders of home. The hill stations were

overt expressions of these longings for home; they sprang up from Murree in what is now Northeast Pakistan to Sillong (present day Bangladesh) to Kodaikanal in the South (Kennedy 1996). The enclaves were established initially out of fear and loathing: a fear that malaria was more prevalent in summer on the Indian Plains and a loathing of summer temperatures at low elevations. In sharp contrast, the stations' climates were reminiscent of Britain. At Mussorie, one of the largest hill stations, the climate was described by one English visitor in curiously complimentary terms, "How delicious is this coldness in the Hills! – it is just as wet, windy, and wretched as in England" (Kennedy, 1996).

With a climate that suited them, the expatriates set about altering the locales even more to their liking. They introduced scores of plants native to northern Europe and the British Isles. Both private and government gardens were assembled with species that would be found in a proper English garden. One resident, Lady Lawrence, wrote in 1839 that at Simla, "Violets, buttercups, wild strawberries and raspberries, and many other old friends abound" (Kennedy, 1996). More ominously, a mid-19th century pamphlet advertising the attractions of Darjeeling in Assam reported that, "Many common English wild flowers bring back to memory the hills and dales and shady nooks and lanes of the fatherland" (Kennedy, 1996). Few, if any, precautions would have been taken to prevent these non-indigenous species from escaping the gardens; more likely, their naturalization would have been deemed further success in inserting the familiar into this foreign landscape.

By end of the 19th century, the Simla flora included garden escapes and ruderals also found in Britain; among them are species that had been deliberately cultivated (e.g. *Cichorium intybus*, *Fragaria vesca, Lamium amplexicaule*, *Papaver dubium*, *Thymus serpyllum*) as well as others that probably arrived as seed contaminants (*Euphorbia pilosa, Sonchus asper, Sonchus oleraceus*) (Collett, 1921). At Ootacamund in the Nilgiris Hills in southern India, the commonly invasive European shrubs *Cytisus scoparius* and *Ulex europeaus* (Westbrooks, 1998) became naturalized along with other garden escapes, such as *Phytolacca dioica*. Other European weeds likely arrived in Ootacamund as seed contaminants: *Plantago lanceolata*, *Poa annua*, *Rumex acetosella* and *Sonchus arvensis* (Fyson, 1932). These weeds benefit initially from the cultivation applied to them deliberately or unintentionally in gardens (Mack, 2000). Non-indigenous woody species (*Populus* spp., *Salix alba, Salix babylonica* and especially *Robinia pseudo-acacia*) were planted to stabilize landslips along ravines in the Simla townsite (Collett, 1921). Thus, even the ravines took on the appearance of European riparian and urban seral forests in which the North American native *R. pseudo-acacia* is a common component (Kowarik, 1995; Muller and Okuda, 1998).

The hill stations of India are only extreme but by no means unique examples of colonists' need for familiar plants in a foreign land. Expressions of this need have repeatedly sprung up worldwide among immigrants. In the United States alone its expression is apparent in the floristic composition in traditional gardens raised by not only English but also Dutch, Italian, and Japanese immigrants (Brown, 1999). The need for the familiar, including familiar plants, is a widely held aspect of human behaviour with important unexpected consequences for plant naturalization.

Allure of the new

A paradoxical aspect of human behaviour is that once the sources of our essential needs are secure and we have erected a familiar, i.e., comforting, environment, we next seek to embellish this environment with diversity, including diversity in plants. Although probably not a basic motive, this desire for varied stimulation and thus the avoidance of habituation seems nonetheless strong (McSweeney and Swindell, 1999). Search for such diversity is expressed in many ways, including the universal tendency to collect objects, for their diversity alone, whether cars, coins, dolls, guns, baseball cards, stamps, books, or art (in all its forms).

Collectibles share several criteria. The objects need to share some commonality (e.g., same era, author or geographic source), have permanency (or at least within the interest span of the collector), and not be so common as to present no challenge or entertainment in the acquisition itself. Further incentive is provided if some objects are rare. After all, where is the entertainment if all possible objects within a commodity can be readily obtained?

Given this strong incentive or preference to acquire non-essential items for relaxation and entertainment, it is not surprising that the collecting of non-indigenous plants emerged early (e.g., the hanging gardens of 6th century BC Babylon, Hobhouse, 1997). Medieval European gardens were often largely composed of herbal and medicinal plants, including non-indigenous species (Brown, 1999; Leach, 2000). But the desire for assembling strictly ornamental species found widespread expression in the 17th century, especially with European trans-oceanic exploration, public excitement with the botanical discoveries from these expeditions, and the emergence of a segment in European society who could afford ornamental gardens (Hobhouse, 1997; Leach, 2000). Establishment of far-flung colonies and trading stations, or both, by the French, the Dutch and especially the British, provided the further opportunity for horticulturists to enter newly-explored countries (McCracken, 1997). By at least the mid-18th century, quests for potential horticultural species were part of the stated missions of the government-sponsored European expeditions fanning out across the globe (McCracken, 1997; Musgrave *et al.,* 1999), including Asia.

For centuries, Europeans had held a fascination for the Orient (Brown, 1999). Yet the Oriental trade in any commodity, including living plants, had been infrequent and difficult (Cox, 1945). Enough was known however of Oriental floras by 1800 to suggest that many Oriental species would tolerate the climates of Western Europe (Spongberg, 1990). Colonization of much of South-East Asia by the French plus the establishment of expanded trade with China and Japan through British and American initiatives in the mid-19th century (Wiley, 1990) provided the first opportunities for sustained plant collecting in this vast region. Collectors, either employed by governments (including employment through government-sponsored botanic gardens, such as Kew) or wealthy patrons, began arriving in the Orient (McCracken, 1997; Musgrave *et al.,* 1999). Throughout much of the 19th and early 20th century there was a growing progression of plant collectors, who criss-crossed China, Japan and Korea; they were largely responsible for introducing Europeans and North Americans to the diverse flora of eastern Asia (Cox, 1945; Spongberg, 1990; Brown, 1999).

Among species they introduced through the horticultural trade are some notorious plant invaders. The American, George Rogers Hall, collected *Lonicera japonica* (Japanese Honeysuckle) (Spongberg, 1990), an aggressive invader in the understorey of forests in the eastern United States (Schierenbeck *et al.,* 1995). Another American collector, Thomas Hogg, reputedly introduced *Pueraria lobata*, or kudzu (Spongberg, 1990), the scourge of disturbed land in southeastern United States (Westbrooks, 1998; Blaustein, this volume). Even if Hogg was the first purveyor of kudzu, he was not the last; it was available directly from Japan in the 1890s and also appears among the *c.* 1900 accession records of the U.S. Plant Introduction Service (Mack, 1991).

Throughout the 19th century plant nurserymen sought to satisfy the growing public interest in horticulture and gardening, particularly gardening with non-indigenous species. The influential English gardener, William Robinson (as cited in Leach, 2000) extolled the virtues of foreign plants in purple prose: " … there can be few more agreeable phases of communion with nature than naturalizing the natives of countries in which we are infinitely more interested than in those of which greenhouse or stove plants are native." In Britain, the largest commercial nurseries, such as James Veitch & Sons and the once allied firm, Robert Veitch & Sons, both employed plant collectors overseas (Musgrave *et al.,* 1999). The Orient was a special object of their collecting activity. Once introduced into the horticultural trade, newly discovered Oriental species could be rapidly traded and exchanged worldwide. Thus, a species introduced by the

Veitch firms in Britain would appear soon in Western European and North American nursery catalogs. The zeal of collecting for diversity itself is illustrated by the enormous holdings offered by just one German nursery (Haage and Schmidt) in 1868 – more than 12,000 taxa (Mack, 1991), which rivals, if not exceeds, the largest nursery holdings today.

Passion for collecting some plant families and genera reached psychological extremes. This phenomenon was and is still expressed in the collecting zeal for Rhododendrons and the Orchidaceae (Postan as cited in Brown, 1999; Reinikka, 1972). Compared with other plant groups (e.g. grasses, Asteraceae), few orchids and rhododendrons have become persistent. Among these species the most notorious example is *Rhododendron ponticum*, one of Britain's most pernicious alien plants (Cross, 1975). Although orchids are commonly obligate epiphytes and often have requisite pollinators, a few orchids have also become troublesome naturalized species: *Monadenia bracteata* in southern Australia (R. Groves, pers. comm.) and *Arundina graminifolia* in Hawaii (Wagner *et al.,* 1990).

Growth of maritime trade throughout the 19th century fulfilled public desire for floral diversity in everyday surroundings. This traffic's effect on the distribution of the earth's flora is often underestimated: never before had so many species been transported to so many new ranges in so short a time span. The 18th century ditty played by Washington's victorious troops at Yorktown, Virginia in 1781, "The World Turned Upside Down" (Pickering, 1975), could be an appropriate anthem for this phase in the earth's floristic history.

What's new? search for the next "new" horticultural species

We remain susceptible to the same incentives as have always driven humans, of which the pursuit of diversity and change is important. Incentives remain strong for acquiring living plants and in turn for moving them into new ranges, thereby inadvertently providing the opportunity for their naturalization. Given the strong link between the global transport of plants and their potential naturalization, the future course of plant invasions becomes substantially influenced by the future of horticulture. The important questions remain, "which species will be exported?" and, "when and where will they be introduced?" These questions have intrigued biologists for over a century (Mack *et al.,* 2000), but they now take on increased importance with the coupling of rapid and voluminous global trade with falling trade barriers (Jenkins, 1996).

The public's preferences change in landscaping and horticulture (Hobhouse, 1999; Leach, 2000), but selection criteria for ornamental plants do have long-standing criteria. Nurserymen diligently search world-wide for species that will be the next commercial successes; their searches are honed by their perception of the public's current choice in plants. Bright, bold flower color probably remains the supreme criterion; further important flower characteristics are large size, longevity, and fragrance. These criteria explain, for example, the perennial popularity of tulips (large flowers with vivid and varied colors) but also their market limitation – a short flowering season and no fragrance. Among woody perennials the appearance of the foliage also becomes important; variegated (Leach, 2000), highly or unusually dissected foliage remains in demand (A. Carle, pers. comm.). Newly introduced varieties of edible fruit present another arena where color is often supreme. The gradual selection principally for color over the last 130 years has transformed the widely-sold apple variety "Delicious" into a bright, uniformly red fruit (P. Andrews, pers. comm.); its taste, however, bears scant resemblance to the fruit of the ancestral stock (R. N. Mack, pers. obs.).

As illustrated above, the acquisition of species themselves, especially species heretofore unknown in cultivation, remains a strong motivation and can override plant attributes, such as flower and foliage color. Consequently, future naturalizations will likely arise from plants

native to regions insufficiently explored for horticultural species. In this regard, China is a once and future source of many horticultural species. The attractions that drew 19th century plant collectors to China remain: a diverse flora across a range of environments that are similar to large swaths of North America and western Europe (Qian and Ricklefs, 1999). In a sense, the work of the early European and American collectors was interrupted. The government of China became increasingly unstable in the first three decades of the 20th century; Joseph Rock, last of a long line of western plant collectors, suspended his China travels late in 1926 as the civil unrest steadily increased (Spongberg, 1990). Civil war continued before and after World War II; it ended in 1949 with establishment of a government that had few dealings with the West. As a result, there was little or no export of horticultural species or plant collecting by westerners for decades. As recently as 1985, Cox bemoaned the slender chances of resuming any rhododendron collecting in Xiang and Yunnan.

Resumption of large-scale and sustained trade with the West in the past decade has meant that Chinese horticultural material is once again arriving overseas. Seventy-five years of little or no opportunity for plant importation from mainland China by western horticulturists has produced much pent up enthusiasm for this new access. The recently published, "The Garden Plants of China", begins, "Nowadays it is possible once more to visit most parts of China, to repeat and extend the journeys of the famous plant explorers of the past, and to collect many beautiful plants not previously brought into cultivation or, in many cases, even known" (Valder, 1999). This unbridled enthusiasm is unfortunately not coupled with attention to the potential hazards arising from horticultural introductions from China. For example, Valder (1999) also extols the horticultural and landscaping value of *Ailanthus altissima, Lonicera maackii, Melia azedarach*, and *Sapium sebiferum*. Each species has however become pestiferous in the United States (Westbrooks, 1998) and has the potential to become naturalized and even invasive in other temperate environments.

Enthusiasm for the acquisition of heretofore unknown or unavailable species is not limited to the Chinese flora. China may hold little interest for collectors who live in deserts or other arid areas, even though western China is arid. Their attention has instead long centered on succulents and other plant forms that tolerate prolonged aridity (Anderson, 1998; Levick, 2000). Increased opportunity for collectors to reach previously inaccessible parts of southern Africa and Arabia present the possibility that some native species from these regions could become naturalized in the arid regions of the United States. Some amateur collectors now have hundreds of species in their gardens, products of their own collecting trips for Aloes and other succulents in Yemen, Madagascar and southern Africa (Levick, 2000). Plant escapes do occur from arid gardens. For example, the attractive perennial grass *Pennisetum setaceum* (fountain grass), a native of north Africa, is now widely sold in the United States (Isaacson, 1996); it has also become naturalized in Arizona and southern California (Hickman, 1993). In 1990, I saw *P. setaceum* for sale in a nursery in Rancho Mirage (near Palm Springs), California. At the same time the grass was growing abundantly up the ravine behind the nursery in a clearly uncultivated site. Such opportunities for naturalization have occurred repeatedly (Healy, 1958).

Aside from historic frenzies for acquiring some plants, such as tulips (Hobhouse, 1999), collecting ornamental species would initially seem among the most innocuous and salubrious of pastimes. Ironically, this pursuit of the new continues to contribute substantially to moving potentially invasive plants around the world (Groves, 1998; Mack and Erneberg, unpublished data). Needed is widespread awareness that, while most of this activity has solely beneficial effects, there is a fraction from which enormous environmental and economic damage can spring (Groves, 1998).

Conclusions

Humans will continue to introduce plants around the world, driven by the same motives or primal urges that have always spurred this transport. These new plant immigrants will present further challenges to the basic questions of invasion biology: which species will be dispersed in the future, what will be their native ranges and their locales of introduction, and what will be their fate in these new locales? (Mack *et al.,* 2000). An understanding of our motivations for dispersing plants will play a huge role in answering these questions.

New crops and forage species will continue to be touted and introduced. For example, *Solanum muricatum* has been proposed for commercial development due to its edible fruits (Prohens *et al.,* 1996); *Passiflora incarnata* has also been touted, even with the knowledge that it is already a "minor agricultural weed" and could become naturalized (McGuire, 1999). But compared with other categories, few edible species will be introduced, a consequence of the aforementioned human reluctance to adopt new foods. Introducing forage species to new ranges will also continue, even though the post-release record of putative forage species is decidedly mixed (Lonsdale, 1994; Mack, 1999). Selection criteria for these species include their requiring little or no cultivation (McArthur *et al.,* 1990), which is ironically a chief attribute among naturalized species (Mack, 2000). Here again, the number of species that are likely to be introduced is comparatively small, especially as the potential hazards of their release become more widely recognized (Lonsdale, 1994).

Species introduced as ornamentals, i.e., for aesthetic reasons, will remain by far the largest group from which invaders will emerge. In this regard, the public's changing preferences are all important. Predicting which species will become naturalized will have at least as much to do with their possession of traits deemed desirable by the buying public, as whether the species have dispersal mechanisms or produce many small seeds (cf. Rejmanek and Richardson, 1996). Choice of the locations from which species will be drawn will continue to be widespread, but regions heretofore inaccessible, such as China, are likely targets of future intensive horticultural collecting (Cox, 1985; Valder, 1999).

The motivations and incentives that cause us to move plants around the world have caused enormous good: industralized societies could not exist were it not for the wholesale establishment of plants in vast new ranges (Hodge and Erlanson, 1956; Harlan, 1975; Viola and Margolis, 1991). Needed now is societal awareness of the hazards of the indiscriminant global dispersal of plants (Holt, 1999), coupled with careful shaping and directing of this intense interest for plant importation into choices that minimize plant naturalizations (Smith *et al.,* 1999). As unlikely as it might seem initially, understanding human behaviour in relation to plant dispersal will prove as important as understanding the biology of dispersed species, if we are to prevent the wholesale homogenization of the earth's flora.

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From ecology to politics: the human side of alien invasions

Tim Low

Abstract

People are animals. Animals often help disperse other species. People were dispersing other species many thousands of years ago, with dramatic consequences. As human ecology changed, the rate of dispersal has multiplied. Where once humans were nomadic, moving between resource patches, now they are sedentary, resources flowing to them on vast transport networks. Alien invaders hitch on the highways. Disturbance to environments often helps them. The values we hold also help them. We exalt mobility, freedom, speed, diversity, progress and familiarity, and view nature mechanistically. The political trend towards globalisation also helps them, for it also exalts mobility, promoting the movement of products and therefore movement of pests, since we cannot devise transport systems that exclude them. At the same time, governments are also losing power to regulate the flow of products. The threat posed by pests is greatly underestimated by almost everyone, including environmentalists. We face an irreconcilable dilemma. We want a world in which people and products are free to move, but other species are not. To help reconcile this dilemma, we could apply cost-benefit analyses to trade and travel to show their true cost, and tax them accordingly. We should change the way we perceive living things, acknowledging the pest threat.

Introduction

The past informs the future. This paper draws upon the past to see where we are heading today, touching upon ecology, history, politics and values. Affluent English-speaking countries are the main focus, with several examples drawn from Australia, the author's home country.

Early history

People are animals. Animals disperse seeds when they carry them in their fur (or clothing) or eat fruits and drop the seeds elsewhere. By spreading seeds, animals can expand their food base. After Krakatau erupted in 1883, birds brought seeds to the barren volcano. Twenty-four fig species (*Ficus* spp.) now grow on the island, along with many other fruit-bearing plants, supporting 23 species of fruit-eating bird and bat (Thornton, Compton and Wilson, 1996). Fruit-eating animals could not live on the islands today had their forebears not brought seeds.

Homo sapiens operates in a like way. Nomadic cultures spread seeds. Groves of wild fruit trees in northern Australia signal old Aboriginal campsites (Hynes and Chase, 1982). Desert tomatoes (*Solanum chippendalei*) were spread outside their original range when Aborigines in the 1970s took their fruits south in cars and scattered the seeds (Peterson, 1979). Humans

contributed to Krakatau's recolonisation by plants, mangoes (*Mangifera indica*) and chillies (*Capsicum anuum*) now growing there (personal observation).

Humans take this process many stages further. We operate knowingly. We spread species that are not usually dispersed by animals, including those with colourful flowers. We disperse animals. We cultivate and practice husbandry. We even grow and spread plants to feed the animals we keep. Today's major weeds include canary grasses (*Phalaris* spp.) supplied as bird seed and pasture grasses sown for livestock. Birds and bats took their habitat to Krakatau, and humans take their habitats with them. Farms and gardens are movable ecosystems that we recreate wherever we settle. Unlike birds, we exercise control over the habitats we create, though not to the extent we would like. Domestic plants and animals often escape our control, and pests (weeds, diseases, invertebrates) always infiltrate our ecosystems. Crop plants are more likely than other plants to become weeds (Williamson, 1994).

People were spreading species a long time ago. Cave sequences from Indonesia and New Guinea show that many animals were translocated in the distant past – possums, wallabies, rats, dogs and the southern cassowary (*Casuarius casuarius*), the world's second biggest bird. Cuscuses (*Phalanger orientalis*) were taken to New Ireland more than 10,000 years ago (Flannery and White, 1991; Allen Gosden and White, 1989) and wallabies to Gebe 8500 years ago (Flannery *et al*., 1998). Trussed animals carried in canoes as food probably escaped or were set free.

These introductions made a difference. Cuscuses on New Ireland defoliate kwila trees (*Intsia bijuga*), sometimes devouring half their leaves (Hensohn, 1998). Dingoes (*Canis lupus dingo*) on mainland Australia (brought 4,000 or so years ago) apparently ousted two marsupial carnivores, the thylacine and devil (Low, 1999), and the parasites they brought now infect kangaroos (Beveridge and Spratt, 1996). Pacific rats (*Rattus exulans*) taken to New Zealand 2,000 years ago exterminated birds. The world's largest lizard, the Komodo dragon (*Varanus komodoensis*), relies on exotic prey (deer, goats) brought long ago to its islands, its original prey (pygmy elephants) having fallen extinct (Diamond, 1987). The early spread of plants and microorganisms must also have produced significant change.

The spread of species today is thus nothing new. It represents the escalation of a very old process (Low, 1999). We may consider it unnatural, yet precedents exist in the dispersal of seeds by animals and early humans.

Alien invasions matter greatly today because our ecology has changed. Human resources have always been patchily distributed. *Homo sapiens* was originally nomadic, moving from one resource patch to another. People today are sedentary, resources travelling to them, flowing into cities on huge networks that run on the stored energy of fossil fuels. Humans keep multiplying, and many have become affluent. The volume of goods keeps growing, and the variety too. People themselves travel for business, leisure and migration. Huge transport networks facilitate the moving, and they are the global highways on which aliens now spread. Wherever there are highways there are hitchhikers. We cannot devise transport systems that exclude pests. Even on the information highway, 'pests' (computer viruses) travel and multiply. Invasions are escalating because more and more products and people are moving. The spread of alien species is now the major influence on global biogeography,

An important contributing factor is disturbance to natural ecosystems. People keep altering environments, creating opportunities for invaders in two ways: by suppressing native species inimical to them; or by creating disturbed environments that invaders have learned to use.

A brief history of values

Our values contribute to our pest problems. Merchant values arose in European cities between the fifteenth and eighteenth centuries, replacing the rigid moral strictures of medieval times. Noted Mumford (1961): "Instead of accepting the traditional products of the regional economy

as relatively fixed and limited, the new merchant adventurers sought to expand production and widen the market: they furthered technological improvements … and they drew widely on overseas areas alike for new materials and finished products."

People themselves became more mobile. "The 'new spirit of society' was on the side of rapid transportation … [T]he hastening of movement and the conquest of space … Mass, velocity and time were categories of social effort before Newton's law was formulated" (Mumford, 1961).

The Enlightenment brought faith in progress. Instead of history turning in cycles like the seasons, of empires rising and falling, and people fatalistically awaiting heaven, man was seen to be rising through stages of progress. Life could be improved by products, machines and personal effort. Optimism peaked in the Victorian Era when, wrote Clarke (1991), "expectations of constant growth and failure-free progress were central to the received wisdom of the age. They had their immediate origin in the day-to-day experience of technological developments: from the first steamships to the latest Atlantic liners, from the wooden frigates to the new destroyers … All of these advantages were a welcome confirmation of the Victorian doctrine of progress … "

Under the banner of progress, acclimatisation societies redistributed plants and animals, creating many of our worst disasters. Over-confidence and invasion go together. Dr Bennett told Australian acclimatisers in 1864 that "Another object of this Society is that of stocking our waste waters, woods, and plains with choice animals, making that which was dull and lifeless become animated by creatures in the full enjoyment of existence, and Lands before useless, become fertile with rare and valuable trees and plants, teeming with excellent fruits, variety of foliage, and gay and brilliant flowers". Nature was a naked garden into which educated men were invited to sow God's most useful seeds. This attitude still survives today among pasture improvement scientists.

Values that developed over hundreds of years strongly influence us today. Those that contribute to our pest problems include love of mobility, freedom, speed, diversity, progress, familiarity, and a mechanistic view of nature.

Mobility

Mobility is the key concept, for a native species becomes an exotic invader only when it is moved. We exalt mobility, which we link with freedom. Automobiles have brought remarkable freedom to affluent nations, and to the affluent in developing nations. Cheap air travel is furthering this trend. The flight of man to the moon is held by many to be humanity's highest achievement. Tourism is the world's major growth industry. Any suggestion that people limit their personal mobility to slow down the spread of alien pests would be strongly resisted.

Consequently, the world is shrinking. We are seeing "the reduction of the world to a single place", and "the decline in the importance of place" (Douglas, 1997). The barriers to movement that keep species in place are disappearing.

Freedom

Values of personal freedom underlie pest problems. Many people believe they have the right to own or import whatever they like. Forbidden foods and pets are commonly smuggled through airports. Australia's papaya fruitfly (*Bactrocera papayae*) invasion, for example, which cost Australia US$115 million, apparently originated from a smuggled fruit (Low, 1999). Consumers expect nurseries and pet shops to carry a vast range of goods. Restrictions on trade are often resented, and lead to self-righteous smuggling. In the United States, where values of liberty prevail, pet shops carry a vast range of exotic species, and many escape to become pests,

in Florida and Hawaii especially. In Australia and New Zealand, where personal freedom receives less emphasis, pet imports are restricted and species rarely escape.

Attempts to tighten restrictions run into opposition from champions of freedom such as economist Milton Friedman. "The urgent need today is to eliminate restrictions, not add to them", he contends, "Restrictions on economic freedom affect freedom in general, even such areas as freedom of speech and press" (Friedman and Friedman, 1990).

Michael (1997) sums up the dilemma: "In the US ethical/legal tradition, one has (in theory) the right to do with one's own (including self) what one wants, as long as it does not infringe on another's rights or well-being. But we are now in a world where almost anything one does as a person, group or nation intrudes on others. We are in a world where our ethics still emphasise rights and autonomy, but where the actual circumstances make imperative close attention to obligations and interdependence.

"We have no ethics, nor do we know what the ethics should be, appropriate for making hard choices in a contentious yet systemic world – a world where, increasingly, everything is connected to everything else over time as well as space; where the 'buck' doesn't stop anywhere; where the consequences of decisions reverberate ever more powerfully because the technologies through which choices are expressed and implemented are ever more powerful."

Speed

Life has speeded up, and because we are always hurrying, we take risks. Tourists and importers expect to pass quickly through quarantine. In a globalised economy, products are expected to move fast. Notes Douglas (1997) "Movement becomes speed". The president of one multinational company (Asea Brown Boveri) asked: "Why emphasize speed over precision? Because the costs of delay exceed the costs of mistakes" (Douglas, 1997). Ballast invaders benefit greatly from quicker shipping times. Back when ships sailed on the wind, very few stowaways survived the long voyages.

Also, we live so quickly we forget what life was like in the past, before the waves of invaders came.

Diversity

Our love of diversity multiplies our problems. When we shop we expect a smorgasboard of choices, be they garden plants, aquarium fish or imported foods. We want a variety of flowers in our garden, and because we extol individualism we want different flowers from our neighbours. We let fashion change our tastes. An Australian survey of nurseries found that 30% of customers wanted something new (Don Scott, pers. comm.). We like botanic gardens – a source of many pests – for the variety of plants they display. We are proudly cosmopolitan, accepting into our cities people from many cultures, who then import products from many lands. We travel back and forth to different countries for the diversity of experience. Diverse cultures create complex matrices of invasion pathways (Carlton and Ruiz, 2000).

Progress

Alien species are often freed in the name of progress. Promoters of progress are more likely to be heard than opponents, since they offer something positive. Also, notes Suzuki (1987), "the benefits of technology are immediate and obvious, but the costs are invariably hidden and unpredictable". Faith in progress creates too much optimism that pest problems can be solved.

Despite problems it may create, globalisation is strongly promoted as progress.

Familiarity

Familiarity breeds acceptance. People like what they know. Alien invaders often occupy humanised landscapes and over time, if they are not too troublesome, become culturally significant, winning acceptance as native species, by traditional and modern cultures. English colonists brought house sparrows (*Passer domesticus*) and rabbits (*Oryctolagus cuniculus*) to Australia and New Zealand to Anglicise the landscape, even though neither is genuinely native to England. Weeds are often adopted by rural communities as medicinal herbs, and sometimes they are spread because of this.

Attempts to control alien invaders are often resisted by those who benefit from them. Australian Aborigines now eat rabbits and Hawaiians hunt pigs and neither wants them controlled. Feral horses are often valued. Gardeners want to keep growing familiar garden plants even when told they cause problems. Bans on familiar but popular products because of pest threats are resented.

Mechanistic thinking

Our perceptions of wild animals and plants are shaped by our familiarity with farm animals and crops and with pets and garden plants. They are also influenced by the power we wield over objects, especially machines and other products we own. Plants and animals are often seen as products. Garden plants sell in supermarkets alongside foods and detergents. Under all of these circumstances, plants and animals appear to be more controllable than they really are. As Suzuki (1988) says: "We groom the planet in our image and see this as an indication that we are in control".

In fact, food plants are more likely to become weeds than other plants (Williamson, 1994). Low (1999) observed: "Plants sold in nurseries are not colourful products invented to brighten people's lives, they are highly evolved organisms programmed to thrive in the wild. Just because they are immobile and unthinking does not make them benign."

Even biologists underestimate invasive species. Diseases sometimes escape from 'secure' laboratories. It seems scarcely credible that fig wasps, 2–3mm long and living for only 2–3 days, could blow 2,000 kilometres from Australia to New Zealand, where they now pollinate cultivated Australian fig trees, which are now setting seed and becoming weeds (Gardner and Early, 1996).

Political developments

The major political trend in the world today is towards globalisation, defined by the International Monetary Fund as "the growing economic interdependence of countries worldwide through the increasing volume and variety of cross-border transactions in goods and services and of international capital flows, and also through the more rapid and widespread diffusion of technology" (Jones, 1999). Trade in the past was hampered by trade barriers, which acted as ecological barriers by inhibiting spread of alien species. Globalisation is the ultimate celebration of movement.

By encouraging movement of products, globalisation encourages movement of alien species, since our quarantine systems – designed to intercept pests – cannot cope with ever-increasing volumes of trade. Quarantine inspections, done properly, are time consuming and expensive. The goal of globalisation is to move products quickly and cheaply. Quarantine inspections are the responsibility of government, yet globalisation, and the trend towards smaller pro-business governments, and the policies of the World Trade Organisation, undermine government capacity to apply quarantine effectively.

As Horsman and Marshall (1994) say: "Effortless communications across boundaries undermine the nation-state's control; increased mobility, and the increased willingness of people to migrate, undermine its cohesiveness. Business abhors borders, and seeks to circumvent them. Information travels across borders, and nation-states are hard pressed to control the flow. The nation state … is increasingly powerless to withstand these pressures".

Every aspect of globalisation promotes the spread of pests, because it also promotes the spread of products. Trade was made easier in the past by globally accepted weights and measures, uniform rail gauges, and long-distance communications using shared languages. Today, pop culture creates global markets for ever more products. Coca-Cola and blue jeans are the cultural equivalents to cosmopolitan pests such as lantana (*Lantana camara*) and the mosquito fish (*Gambusia holbrooki*). Ecological "winners" – those that travel well and thrive in humanised habitats – displace localised species, just as Coca-Cola displaced hundreds of local drink factories. Some biologists warn of a "McDonaldization" of world ecology (Lovei, 1997).

As one consequence of globalisation, manufacture of individual products is increasingly spread across many nations (Gereffi, 1994). Components from many countries are brought together for assembly, providing excellent opportunities for invaders to travel along the many "commodity chains". Commodity chains are continually changing as factories relocate and companies outsource to their best advantage. The more complex the matrices of movement, the greater the opportunities for pests.

Movement of products (and pests) is also encouraged by declining transport costs. As Tom Jones of the OECD notes: "Globalisation is likely to lead to lower freight costs across most transport modes in most countries. For example, the World Bank (1997) reports that the real cost of sea freight fell by nearly 70% between 1980 and 1986. Air freight rates showed similar declines" (Jones, 1998).

Nations that try to control pests by restricting imports face scrutiny from the World Trade Organization. The Agreement on the Application of Sanitary and Phytosanitary Measures (SPS Agreement) advises that member states, "when determining the appropriate level of sanitary or phytosanitary protection, take into account the objective of minimizing negative trade effects" (Nairn, 1996).

Under globalisation the role of the nation state is changing. Many economists and politicians believe that economic crises are brought about by attempts to regulate and restrain markets (Douglas, 1996). Government management of the economy is increasingly seen as redundant and counter-productive. Political power yields to the market place. Modern states have been described as "transmission belts from the global to the national economic sphere" (Scholze, 1997). Governments that become subservient to the movement of products cannot be expected to control the flow of pests.

Lack of awareness

All forms of economic activity come at an environmental cost. Factories pollute, farms erode soil. Alien invasions are the price paid for trade and transportation. Globalisation may bring great benefits, but the costs should be acknowledged.

An extraordinary feature of the free-trade debate is the failure of most participants to recognise bio-invasion as a consequence of trade. The OECD book, *Globalisation and the Environment* (OECD, 1998) makes no mention of alien invasions. Nor does Runge's 1994 book, *Freer Trade, Protected Environment*. Nor does Harvard biologist Douglas Yu's article in *Conservation Biology*, 'Free Trade is Green, Protectionism Is Not' (Yu, 1994). Nor do Suzuki and Dressell (1999) in a trenchant attack on globalisation.

The failure of politicians and business interests to recognise this issue is perhaps not surprising. Environmentalists often complain that advocates of economic growth ignore its

costs. Notes Michael (1991): "so many have deeply vested and powerfully held interests in the status quo (more or less), thereby, strong unconscious as well as conscious needs to deny the reality of the fundamental unrecognised issues … " Says Ehrlich (1997): "The biological and cultural evolution that eventually produced people (including ecologists) has also largely tuned the human nervous system (and presumably those of other animals) to ignore very gradual changes in the 'back-drop' of the environmental stage on which the drama of life is played out".

Cause and effect in invasion biology often seem disconnected. As Low (1999) says: "The power we wield seems incomprehensible – tiny actions ignite explosive consequences. Something as trivial as a seed on a sock or a spore on a shirt can rewrite world history. Someone took a diseased potato to Europe last century and triggered the Irish Potato Famine and a million people died … . We are clumsy giants on a fragile planet vested with powers we cannot comprehend … "

These explanations do not explain why conservationists neglect this issue. How do we explain the failure of Suzuki, a leading environmentalist and bitter critic of globalisation, to grasp the most serious environmental consequence of globalisation? According to Maj De Poorter (pers.comm) of the IUCN Invasive Species Specialist Group, only in New Zealand does a leading conservation group (The Royal Forest and Bird Protection Society) take a major interest in invasions. This is because alien invasions have devastated New Zealand, with most native forest birds now extinct on the main islands. Nowhere in the world is an NGO devoted entirely to alien invaders *in toto* (although such a group may form soon in Australia). This represents an extraordinary omission by conservation groups, especially as many are trenchant critics of globalisation.

Conservationists neglect this issue for several reasons: they are pre-occupied by dramatic events (invasions are often subtle), are reluctant to demonise plants and animals; are ecologically unaware; perceive alien invasion as an old-fashioned issue mainly affecting farmers; or believe the issue is simply one of better quarantine. Another problem is that alien invasions are often viewed in isolation, as a thistle problem or a rat problem or a fire ant problem. The larger picture is overlooked.

According to Michael (1991) "we choose our social causes in terms of our own psychological needs". Many conservationists are disillusioned by humanity, finding solace in the "purity" of untainted nature. In a duality of wilderness and culture, alien invaders do not fit, for they are effectively tainted nature.

Also, the wilderness ethos promotes a holistic approach to nature instead of a classificatory one. Wilderness devotees rarely notice weeds because they cannot identify them.

Conclusions

A dilemma confronts us. "We want a world in which people are as free as possible to travel and to exchange goods and ideas" says Bright (1998). "But at the same time, we *need* a world in which most other living things stay put."

Unfortunately, these two goals are largely irreconcilable. Alien invasions are inevitable when goods and people move. New technology will reduce invasions but will not stop them. We may stall ballast invaders and cut down on petty smuggling at airports, but pests will not be stopped from travelling in cargo, on hulls, or during crises such as war. We should design transport systems with the goal of eliminating invasions, but without expecting success.

The most logical way to reduce alien invasions would be to reduce mobility of people and products. But this will not happen because we value freedom and mobility more than we fear pests. Most world leaders endorse globalisation.

We should at least acknowledge the full cost of mobility. Cost-benefit analyses applied to trade and travel would show their true cost. (Costings exist for several pests travelling the wake of freer trade.) Were the true costs shown, some trade (i.e. bait fish, cut flowers, used farm

machines) might be recognised as uneconomical and be phased out. Travel and trade could be taxed to show their true cost, the money going to quarantine and control (see Jenkins, this volume). Green theorists complain that traditional economic analyses take no account of environmental costs, but alien invasions cost industry so much that traditional analyses are frightening enough.

We could also promote the value of local travel and local produce. "Community" as a value offers a counter to "globalisation".

We should change the way we perceive living things, plants especially. Garden plants, crops, timber trees, pasture grasses, aquarium fish and aviary birds are potential pests, not our servants. Home-owners should practise ethical gardening (Low, 2000) by not growing invasive species and by not dumping garden wastes.

Finally, we need major publicity campaigns all over the world to explain the threat posed by alien invaders, and the human processes contributing to them.

Listening to the Earth: a call for protection and restoration of habitats

Vivian Parker

Abstract

Efforts to eradicate invasive alien plants, in particular by means of chemical herbicides, without addressing the underlying causes of invasions, are likely to be ineffective and may result in further simplification of ecosystems and disruption of ecological processes. The Native American perspective, based upon faith in the wisdom of the Earth, challenges us to take actions to restore the balance to ecosystems that are threatened by the loss of native biodiversity, and to protect intact ecosystems from the types of anthropogenic disturbances that facilitate invasions. A scientific rationale is provided that supports this view.

Introduction

> We have a chance to resist most exotic invaders by having stable ecosystems … What characteristics allow starthistle to take advantage of destabilized systems? To change the emphasis, what species do we keep or restore to the system to resist invasion, or to encourage stability within the system?
>
> Dennis Martinez, O'Odham, Crow

> The problems that we have created cannot be solved at the level of thinking that created them.
>
> Albert Einstein, Physicist

Awareness is growing among resource managers today that biological invasions are complex problems, and that simplistic solutions based on the use of chemical controls may result in unforeseen consequences. This has been addressed by several authors in the literature on invasions (e.g., Orians, 1986; Dahlsten, 1986; Groves, 1989; MacDonald *et al.,* 1989). Biological invasions are ecological, and therefore involve numerous complex interactions between many species, processes, and abiotic factors in the environment. In many cases, invading species may be providing ecological services, and may be important resources for associated wildlife species, especially in degraded urban environments and increasingly, at the urban fringes.

Native American indigenous people understand that the sustainable use of resources is integral to the well being of all life forms on the planet. This perspective, rooted in respect for creation, honours the fundamental wisdom of the Earth to self-heal. Technological solutions to ecological problems are viewed as inappropriate because they usually lead to new, increasingly difficult problems that require new technological solutions. Instead, indigenous resource

managers, relying upon traditional ecological knowledge, challenge us to look closely at the ecosystems in which invasive plants occur, while asking what they might be telling us.

We recognize the role that humans have played in disrupting the balance of nature, and that humans must also play a role in restoring the balance. Policy makers and resource managers must shift the focus of their attention from treatment of the symptoms of ecosystem disorder, to identifying and preventing the causes of plant invasions. Invasive plants are one of the symptoms of an altered biological trajectory resulting from unsustainable resource extraction and industrialization of the planet. We must take actions that will restore the balance to ecosystems that are threatened by the loss of native biodiversity.

The ecological perspective (all things are connected) bears great similarity to the Native American concept of relationship (all things are related). This perspective is necessary for successful long-term restoration of native ecosystems. However, an agronomic bias – which focuses on the negative impact of IAS on agriculture – currently dominates research on invasive plants, severely limiting lines of enquiry into the broader causes and prevention of alien plant invasions. An ecological approach to control of invasive plants requires that the many interactions between species be investigated. For example, evidence for the beneficial effects that invasive species may be having in stressed ecosystems has largely been ignored. The agronomic bias also imposes a value-laden language upon alien species, and may institutionalize the conceptual paradigm that certain plants and animals are bad or even evil. Colonizing invasive plants have been characterized as "aggressive," "choking," "stealing," "corrupting," "harmful," "destructive," and guilty even of "deliberate takeover" (e.g., USDI, USDA, 1999). With the understanding that all life is sacred, we do not think that such characterizations are helpful, and we believe that adherence to this paradigm may result in further harm to the planet.

The purpose of this paper is to focus attention on the causes of plant invasions, and threats to native plant habitats. I will discuss the role of invasive plants in plant community development and evolution of new species, and present evidence that contradicts widely-held assumptions about the effects of invasive plants, particularly in regards to competition. These assumptions have been used to justify use of destructive herbicides. It is my hope that the issues addressed in this paper may provide a starting point for developing a new paradigm, based on ecology and respect for life, rather than on economics.

The complex nature of invasions and global change

Generalizing across all taxa, without distinguishing between their various life histories and habitats, is misleading and should be avoided. I provide some examples below.

Differences between plant invasions and other types of invasions

The great differences between the life histories of plants, animals and pathogens make it inappropriate to generalize across all taxa in regard to invasive species. This is an important distinction. For example, the lumping together of invasive life forms, and the subsequent assignment of their economic costs, is unscientific and has left open the potential for misuse of these figures by special interest groups. Reports such as Pimentel *et al.* (1999) and OTA (1993) combined diverse taxa and effects in order to arrive at aggregate economic costs of invasive species. The Pimentel report included such costs as lost work time for workers who had been bitten by dogs ($85 million per year), and the costs of AIDS infections ($6 billion), although dogs and AIDS bear little direct relationship to the true issues of invasive species and biological diversity on the planet. In the OTA report, fully 96% of the costs calculated were due to 62% of the species, which were all insects and agricultural pests. Since agriculture itself is a primary threat to the biodiversity of the planet (e.g., Ehrlich and Ehrlich, 1981), one could theorize that

these insects are actually doing a service, as they attempt to munch their way to diversity, doing their best to eliminate monoculture farming!

Yet, these reports are widely cited at the local and regional level, in California and elsewhere, in order to gain support for increased bureaucratic budgets for "war on weeds" programmes. Such programmes frequently do not distinguish between target native or invasive alien plants.

The use of herbicides for weed control is a health hazard for Native American Indian basketweavers. Basketweavers may be exposed to herbicides when gathering, or in processing and weaving, when plant fibres are handled. Access to populations of indigenous plant materials has become increasingly difficult in recent years for basketweavers, due to degraded habitats, development, and exclusion from private property. On public forest lands, the increased use of herbicides to remove competing vegetation in conifer tree farms after clearcut timber harvesting, coupled with herbicide use to control invasive plants, has contributed to greater risks for basketweavers from exposure. Additional appropriations for herbicide funding for local county programmes may increase these threats. In addition, local weed abatement programmes have contributed to greater threats to rare and endangered species, particularly aquatic species, and are accelerating the decline of biodiversity, while creating uncertain health threats to the public and polluting water supplies. Indeed, where economic considerations of the effects from invasive species conflict with ecological concerns, history has shown that public health and the environment are usually the losers.

These examples suggest that the use of economic figures to illustrate the costs of invasive species portrays a misleading picture to politicians, the general public, and the media; and while the lumping of taxa to produce such figures may well be the realm of the agricultural economist, their use to protect and conserve planetary biological diversity is questionable. Broad generalizations about invasive species should be avoided.

Differences between island invasions and continents, or terrestrial and aquatic environments

Similarly, the differences between the ecology of *islands* and *continents* (e.g., Darwin, 1859; Elton, 1958; Gorman, 1979; Mueller-Dombois, 1981; Loope and Scowcroft, 1985) are such that I will limit this discussion to the issues regarding invasive plants on the North American *continent.* A survey of impacts from invasions by Simberloff (1981) illustrates the differences between the impacts resulting from animal invasions (versus plants) and island invasions (versus continental). Looking for evidence of exclusion based on interspecific competition that led to extinction, he found that although often hypothesized, the experimental evidence for such processes was mostly lacking. A literature review of the community effects of introduced species (covering 850 species across all taxa – plants, animals, insects, fungi, etc.) found that 79% of the species for which data existed had *no measurable effect whatsoever* on the species in the resident community. But where extinctions had occurred, in over 90% of the cases, the interactions occurred on *islands,* and these were predator/prey relationships among *animals*. The greater risk of permanent ecological transformation from introduced species in island habitats should underscore the need to ensure that natural area reserves on the continents do not become so fragmented that they *become biological islands.*

Similarly, aquatic invasions – particularly in freshwater environments – are very different from terrestrial plant invasions. With high levels of endemism, freshwater ecosystems resemble islands and face similar threats resulting from biological invasions. Invasions in freshwater fisheries have also been linked to high levels of pollution and altered hydrological regimes which have so altered native habitats that they may no longer be suitable for the native assemblages (Moyle and Leidy, 1992). Ironically, high use of herbicides to counter perceived ecological threats in plant communities may increase the more serious threats encountered by native aquatic species in freshwater environments that receive the run-off from sprayed areas. It

is evident that priorities for control measures must be based on a sound understanding of the true ecological impacts to biodiversity from invading species, and not simply be based on economics or expediency.

Plant invasions and global change

The issue of IAS is as complex as any other in biology today, and is worthy of our greatest efforts to understand, in order to respond in ways that will not result in further harm to the environment. The effects of industrialization of the planet are beginning to be felt in synergistic ways, most notably global climate change. Many scientists now believe the Earth's biota are headed for a massive extinction event (e.g., Ehrlich and Wilson, 1991). Evidence that animals are moving away from the equator in response to rising temperatures is increasing daily. Plant populations, however, historically have been found to experience tremendous time lags in their responses to climate changes, with some forest communities lagging by 1000 years or more (Davis, 1987; Webb, 1987). Palynological (fossil pollen) evidence suggests that for short-lived herbaceous plants, local populations which cannot evolve physiological adaptations quickly enough to adapt to climate fluctuations tend to die out, while other populations build up in new localities where conditions are closer to the optimum for the species. The ability to disperse into new habitats is the most critical factor for plant survival in response to global changes.

In this regard, the global movement of seeds and propagules by humans may actually enhance opportunities for the future development of plant communities. This is an area that is ripe for research. Whittaker (1977) determined that "Diversity evolves as a self-augmenting phenomenon: evolution of species diversity provides resources (and controls) that make possible additions of further species to the community." The individualistic nature of species distribution has been well described by Whittaker (1967) and confirmed by the palynological studies of Davis (1987). Communities are shifting assemblages rather than tightly determined units, responding to many variables in the environment including stochastic events. Davis (1987) suggests that "alternative communities" have arisen many times during the interglacial times of the Quaternary period, which occurred perhaps 18 to 20 times, or roughly once every 100,000 years and lasting only 10,000 to 20,000 years.

To what extent does the present mixing up of the planet's biota present an opportunity for heightened diversity after the dust settles on the present extinction spasm? To my knowledge, this possibility has not been addressed anywhere in the current literature concerning plant invasions.

Further underscoring this potential is the fact that the primary mode by which continents and islands have become colonized and populated with unique and rich biological assemblages is through migration and subsequent speciation (Futuyma, 1986). This mode is so fundamental to evolution that attempts to predict, quantify, and evaluate the effects of biological invasions have confounded ecologists; after all, the distinction between native and alien species is arbitrarily defined by temporal and spatial scales of human derivation.

Impacts from invasive species also need to be analyzed in terms of their global distribution. Many plants that are invasive in one country are actually rare or threatened with extinction in their country of origin (e.g., *Carpobrotus edulis, Carduus nutans, Lepidium latifolium*). If optimum conditions are found in a new locale and a previously threatened species is found to thrive there, it does not make sense to attempt to extirpate it – particularly when conclusive evidence for strong or long-term effects is lacking, as is usually the case with plant invaders.

Some scientists have distanced themselves from consideration of these issues, arguing: "If we admit that this is a natural evolutionary process, it excuses us from the incentive to implement conservation measures". On the contrary, I am not suggesting that we suspend conservation efforts at all. We should do everything we can to protect and conserve rare species and biodiversity, and to prevent further introductions of invasive species. However, if we do not halt the present trajectory of habitat destruction across the planet, we may wind up with

habitats that support nothing at all. We must be careful that in our zeal to secure short term success, we do not create additional problems that may result in far worse problems over the long term.

Survival strategies for generic lineages

Plants must be able to disperse into new habitats in response to changing environments, whether the changes are anthropogenic or due to cyclic climatic changes (Jablonski, 1991). Dispersal is the most limiting factor for new recruitment (Tilman, 1997, 1999; Davis, 1987); barriers to dispersal today are likely to be related to habitat fragmentation due to agriculture, development and urbanization. Historically, plants have been the least likely and the slowest to suffer extinction. And competition has not been documented as a factor in exclusion or extinction for any plant species (Crawley, 1987). Even in the case of introduced pathogens, like chestnut blight, ecologists are uncertain what, if any, long term effects the temporary loss of chestnut (*Castanea dentata*) on the North American continent will have (Day and Monk, 1974).

Species with highly specialized niches and restricted distribution are particularly vulnerable to extinction, whereas widespread genera are more likely to survive mass extinction (Jablonski, 1991). Following such events, those species with wide geographic distributions and wide environmental tolerances are generally the only survivors. Thus these wide-ranging habitat generalists may be necessary to provide the raw material for future speciation. Cross-breeding has occurred frequently between remnant populations of severely depleted taxa, resulting in hybrid offspring. When viewed as a natural phenomenon, this can be seen as a survival strategy for the phylogenetic lineage. If efforts to remove invasive congeneric species are not coupled with efforts to protect declining populations of threatened species from further habitat destruction or exploitation, this survival strategy will be truncated, and further losses of biodiversity may result. The greatest threat today to plant survival world-wide is habitat destruction and deforestation (Ehrlich and Wilson, 1991). Although some analysts have attempted to ascribe threat status to invasive species, in reality, virtually every significant invasion has been preceded by habitat modifications by *Homo sapiens*, such that the invaded ecosystem was already severely disturbed before being invaded.

Diamond and Case (1986), for example, found that extirpation of native birds in New Zealand and Hawaii has been falsely attributed to exotic species competition; the primary cause is more likely to be "introduced predators and diseases and habitat destruction before the exotics became numerous." Similarly, on Guam, the use of DDT decimated the native endemic bird populations (Jenkins in Diamond and Case, 1986); the later introduction of the predatory brown tree snake is widely cited today as the sole reason for the demise of the birds of Guam (e.g., Pimentel, 1999).

In the western region of the US, the collapse of the Great Basin ecosystem has been attributed to the spread of a European annual grass, cheat grass (*Bromus tectorum*) (Mack, 1986). However, the use of the herbicides 2,4-D and 2,4,5-T from the 1940s until the present time, to kill native sagebrush and other shrubs and to increase grass for grazing livestock, combined with overgrazing of the sagebrush ecosystem, are the initial disturbance factors that preceded establishment of cheat grass. As early as the 1960s, scientists had noted that the global use of 2,4-D had resulted in a *global increase* in weedy grasses that are tolerant to the herbicide (Fryer and Chancellor, 1970). Today, the use of selective herbicides like clopyralid to control yellow starthistle (*Centaurea solstitialis*) and other knapweeds has resulted in an explosion of the invasive medusahead grass (*Taeniatherum caput-medusae*) in the western region of the U.S. Several authors have warned against the use of herbicides to eradicate species, since the substitution of one invasive species for another is such a common phenomenon (Groves, 1989). In crop systems, new pests are continually arising, and the evolution of pesticide-resistant ecotypes is a very real and on-going occurrence (Baker, 1974, 1999). This suggests that treating

natural areas as if they are agricultural systems may result in similar outcomes, resulting in simplification of natural areas (Auld and Tisdale, 1986; Groves, 1989; Hobbs and Humphries, 1995).

Large numbers of reproducing individuals should greatly improve the probability of random mutations occurring that might result in superior adaptations conferring greater evolutionary fitness. As a species we have only been observing nature using the tools of modern science for a very short period of time; the opportunities to observe evolution in action may be found at the boundary between populations increasing exponentially and those on the very edge of extinction. For example, the molecular mechanism responsible for morphological mutants in the invasive plant yellow toadflax (*Linaria vulgaris*) has recently been elucidated (Cubas *et al*., 1999). The additive effects of global warming and ozone depletion provide an additional incentive to search for evolutionary effects. In fact, genomic instability in plants resulting from elevated ultraviolet radiation has recently been demonstrated (Ries *et al.,* 2000). Rather than placing roadblocks to what may be mechanisms for self-repair in damaged ecosystems, ecologists should be working to maintain stability in ecosystems that are at risk.

While examining the contradictory evidence for the "slow competitive elimination" models of communities, Chesson and Case (1986) noted "they are theories of conservation of the existing species pool and do not address the question of how that pool comes about in the first place". Perhaps it is time for ecologists and evolutionary biologists to begin to address this question in the context of invasive species.

Competition and plant invasions

Studies by paleoecologists of plant community development over geologic timeframes have shown that, for flowering plants, "communities can accumulate higher and higher numbers of rarer and rarer species, with no obvious ceiling on species richness" (Knoll, 1986). Empirical evidence (Lonsdale, 1999; Williamson, 1999; and Stohlgren *et al.,* 1999), suggests that continental habitats can indeed absorb additional plant species without reducing native species diversity (richness and evenness). This is presumably due to high resource availability and a wide variety of other gradients.

Supporting experimental evidence for this has also been demonstrated. A four-year study in Minnesota by David Tilman (1997) found that, after adding up to 54 species of seeds to several experimental plots, the plots seeded with the most species were 83% higher in total species richness than the control plots, *while total cover of the pre-existing species remained stable*. This suggests that the new species were simply filling in unoccupied sites. While not discounting the role of interactions between species, Tilman concluded that plant species composition, abundance, and diversity are strongly limited by the ability of plants to disperse seeds. Thus, anything that interferes with this process is likely to result in declining plant populations.

Although invasive plant populations can displace numbers of native species at the stand or alpha diversity level, evidence has shown that at the landscape scale (beta and gamma diversity), with increased area, native diversity increases in both richness and equitability (Forcella and Harvey, 1983; Crawley 1987). As Parker *et al.* (1999) point out, "the fact that one can measure a large response to an invader in a few small quadrats constituting a fraction of a species' range may have little to do with a true population impact." Indeed, areas rich with native plant diversity are often rich with alien plant diversity as well (Stohlgren *et al.,* 1999; Lonsdale, 1999). And, no extinctions have ever been documented to *plants* as a result of competitive displacement from another, introduced *plant* species (Harper, 1965; Crawley, 1987). These are significant and important distinctions to be raised.

Nevertheless, protection of habitat is the greatest insurance that viable native plant populations will remain to provide the necessary seed sources for recruitment and dispersal, regardless of the source or type of global changes that occur.

With this in mind, if the proliferation of IAS is indeed a *natural response* to the driving agent of disturbance, industrial *Homo sapiens*, then the role of these invasions in maintaining ecological integrity must be investigated. This line of enquiry has been severely suppressed in the current agronomic paradigm. An exception is Walter Westman, who pioneered this concept in his studies of the effects of pollutants on native and alien vegetation. Westman *et al.* (1985) were able to demonstrate that deposition of chemicals from urban and industrial pollutants resulted in soil changes that facilitated the growth and spread of alien species that had evolved into pollution-resistant ecotypes. Pollution also caused the death or mutation of native mycorrhizae fungi, and prevented formation of nitrogen fixing nodules on plant roots. The proliferation of herbicide-resistant weed ecotypes, of course, has been well known for half a century (Harper, 1956; Baker, 1974). In 1990, Westman suggested that in many cases, weed species may be better adapted than specialized native species to deal with the stressful conditions of habitat and climate change and pollution. Thus, alien species may also serve an important role in soil binding and nutrient retention in degraded habitats that are no longer suitable for native species (Westman, 1985, 1990).

The Native American perspective

Native American people, and perhaps all indigenous people, are especially well qualified to understand the potential for harm that is the outcome of uncontrolled growth and expansion of alien or non-native populations of species. While Native American people have themselves been the victims of invasions of their homelands by the arrival of immigrants on this continent, they have generally not viewed new plant introductions with the same alarm that western scientists have. According to Native American herbalist Betty Hall (Shasta elder), newly introduced plants were often welcomed, and new uses were found for them. Closely related plants, such as the thistles in the genus *Cirsium,* were used as food and medicine in similar ways across the continent, whether native or not. And Indian people are quick to notice how the birds, butterflies, and other insects are drawn to species otherwise thought of as weeds by western scientists. Plants that are considered weeds often have medicinal values, such as wormwood (*Artemisia* sp.), mullein (*Verbascum thapsus*), sea fig (*Carpobrotus* sp.), St. John's wort (*Hypericum perforatum*), milk thistle (*Silybum marianum*), and blackberry (*Rubus* sp.), in California. Reetha Amin (Atsugewi elder) refers to these types of plants as "healers". She says these plants heal people, and they heal the Earth too; that is why they grow in waste places, on disturbed ground. If this is so, then when we kill these plants because they are not native species, is it possible that we are causing further harm, by interrupting the natural healing process? These plants are wild; they are self-directed. As such, they do belong to the Earth.

Ancient indigenous cultures, who have occupied areas of the North American continent for 10,000 years or more, have direct cultural experience from thousands of years of direct interaction with the land. Many tribal people have stories dating back to time immemorial, which carry warnings about a previous time, when people made mistakes dealing with the environment. The stories are meant to serve as a warning to each generation, so the same mistakes are not made again. As Winona LaDuke (Anishinabe) has stated "Natural law is pre-eminent", and failure to obey this system of law will have inescapable consequences (LaDuke, 1995).

Navajo story tellers, for example, tell of a time when plants ruled the Earth. Many of them were harsh plants, and covered with dangerous spines. If the Earth is not cared for properly, we are warned, this time could return. Elders, when questioned about the current sweep of prickly invasive species showing up now in the western desert regions of their homelands, reply that the Earth is responding to the damage that unsustainable land use has brought with it (Burnside, pers. comm.).

Evolutionary theory could also predict just such a response. Adaptations such as prickles, thorns, and sharp awns help to deter grazing, and plants with these adaptations are preferentially avoided under the pressure of grazing livestock. Such adaptations also result in the species being pre-adapted for rapid establishment in grasslands as weedy species where livestock grazing predominates (Naveh, 1967; Groves, 1986). As such, the proliferation of these weeds are a natural response.

Humans and biodiversity, then, are not mutually exclusive. Until the advent of modern agriculture which requires supplemental winter feeding on the range and overstocking, the European chalk grasslands, for example, contained some of the highest floristic alpha diversity in the world (Naveh, 1967). These specialized habitats evolved during 8-10,000 years of association with humans and grazing livestock. Humans, as the keystone species, then as now, are the driving force that controls the trajectories of community development.

Plant communities are a reflection of the processes that built them; where these processes are allowed to continue, the communities will continue to reflect them (Watt, 1947). As indigenous ecologist Dennis Martinez (O'Odham, Crow) has said, "Two different cultural world views have led to two different types of landscapes in North America. Both indigenous cultures and industrial cultures have created unique landscapes. Both have dealt with ecological uncertainty and change in distinctive ways. Both have modified the 'natural' landscape according to their own cosmologies, myths and belief systems" (Martinez, 1999).

California Indians and biodiversity

Today it is widely acknowledged that, in California, the abundant biological diversity and resources of the region which so delighted the eyes of the first immigrant Europeans in 1769, was the direct result of the active land management techniques of the indigenous people (Anderson, Barbour, and Whitworth, 1998). Fire was the most important management tool, and was used for many purposes, including clearing brush, maintaining grasslands and meadows, and improving browse for deer. It was used to modify species composition in the understorey of forests, to reduce fuel accumulation that otherwise might result in intense fires, and to promote and improve the production of high quality basket and fibre materials. Indian ecological stewards also engaged in pruning, sowing, planting, weeding, tilling, dam building, and selective harvesting (Shipek, 1993).

The seeds of many fire-dependent annuals and grasses were utilized by the Indians for food, and were much more widespread in pre-contact times. Without the regular use of fire, these species now survive only in dormant seed banks beneath forest canopies, awaiting the advent of forest fires to germinate; many have now become rare species. It is understood by most ecologists that fire was the most influential disturbance factor in the California floristic province, and virtually all plants (at least from sea level to upper montane forest elevations) were well adapted to fire. Thus, the departure of the Indian influence from the region, combined with modern fire suppression policies, has resulted in a significant disruption of the historic disturbance regime, and a subsequent decline in biological diversity. With the loss of native seed sources, and widespread land conversion to development and agriculture, invasive plants have become well established.

Interrupting the present trajectory

Balance, or stability, meaning ecosystems that maintain all of the functions necessary for sustainable reproductive capacity for the organisms that live in them, is a property that is dependent upon many things. However, most investigators point to the importance of the concept of keystone species or critical link species (e.g. Paine, 1966, 1980; Gilbert, 1980; Westman, 1985) and maintenance of disturbance regime (e.g., Westhoff, 1971; Connell, 1978;

Denslow, 1980; Peet, 1983; Sousa, 1984; White and Pickett, 1985) in the conservation of diversity and functioning ecosystems. Thus, any effort to restore balance to native ecosystems must include an effort to identify historical keystone species, critical link species, and the historical disturbance regime, and to restore or re-introduce them, if necessary.

Restoration of natives through planting and seeding

Many researchers have concluded that *resistance* to invasion is largely a factor of the *amount of resident biomass or cover* (e.g., Peart and Foin, 1985; Rejmánek, 1989), while maintenance of the *historical disturbance regime* has been identified as crucial for the survival and conservation of plant communities (Watt, 1946; Noble and Slatyer, 1980; Denslow, 1980; Grubb, 1986; De Ferrari and Naiman, 1994). Thus, these two components of habitat suitability must be present for native plant communities to persist.

It follows from this that restoration of the native seed bank through planting and reintroduction of native propagules may be necessary. Efforts to eradicate *undesirable* plants are likely to be unsuccessful without a clear understanding of what species *are desirable.* If these are no longer available for recruitment and dispersal, then eradication efforts are likely to be followed by reinvasion or invasion by a new, perhaps worse, invading species (Auld and Tisdale, 1986; Groves, 1989).

The need for restoration is frequently neglected because the main drive for invasive species control is economic. When invasive species are causing economic losses, then control measures focus on removing the invader. But this is not an effective long-term strategy.

Protection of intact ecosystems, age of plant communities and invasion potential

Protection of uninvaded, mature communities, as bulwarks of vegetational resistance, should be a critical objective for maintenance of historical plant communities. That mature plant communities are inherently more resistant to alien plant invasions has been discussed elsewhere (Connell and Slatyer, 1977; Baker, 1986). Rejmánek (1989) compared invaders in three successional series from central Europe, and found an exponential decline of the proportion of all invaders with increasing seral age. A similar study of invasion in the Mississippi delta found that even though all the plant communities were subject to a constant annual flood of propagule deposition, in the older seral stages only two invaders were found in stands 30 years old or more, and only one invader in forests older than 50 years (Rejmánek *et al.,* 1987). This function of "successional repairing" was found to be a universal trait for continental floras. Recovery of island habitats was found to be much slower or incomplete.

Ewel (1994) observed that intact plant communities – those that have not been degraded or disturbed – are not only resistant to invasion but may be, in fact, non-invasible. D'Antonio *et al.* (1999) found evidence for this in dense chaparral, and in undisturbed forests, although it is acknowledged that there is no such thing as a community that is not subject to some kinds of natural disturbance (e.g., Sousa, 1984). A similar conclusion was reached in a study of invasions and disturbance in forests on the Olympic Peninsula in Washington (DeFerrari and Naiman, 1994). Forest stands with mature trees (>150 years old) with closed canopy had the lowest number of alien species, while clearcuts and alder flats had the highest number of aliens. Alien plants peaked in 3 to 7 years after clearcutting, and began to decline, with increasing canopy shade. Alien species also decreased with distance from the highway and with increased slope.

Paleobotanical evidence appears to confirm this finding. Even when an invading plant was found to be competitively superior in a new climatic regime, the resident climax vegetation type may resist occupation for 1,000 years or more, due to the reproductive disadvantage of the invading species, which is unable to establish seedlings in sufficient quantities in the resident

ecosystem (Cole, 1985). This vegetational inertia is further enhanced by at least several unique habitat modifications that the resident mature vegetational series exerts on the environment, thereby creating its own favourable microclimate. These include subcanopy insolation that controls local humidity and precipitation (Azevedo and Morgan, 1974) and a unique soil chemistry developed over thousands of years of decomposition of its own leaf litter and needles. Crawley (1989) proposed that these constraints are the result of higher levels of structural and biotic diversity or linkages: "the more rules that apply, and the more rigorous the selection process, the harder it is for a given species to invade". While older ecosystems exhibit high resistance (high inertia) to invasion, they are also the slowest to recover when severely disturbed (low resilience-elasticity).

Cairns and Pratt (1990) demonstrated that anthropogenic stress could lead not only to chronic impoverishment and simplification of communities, but that this impoverishment could lead to further loss of resistance to invaders. They experimentally added trace levels of toxic materials to microbial communities of various ages. The result was that species loss in mature communities was only 30%, compared to 80% loss in immature communities. And, more species in the community also provided it with some type of buffering ability. The authors concluded that "simple communities are not capable of the same responses to stress as more complex communities … The result of these differences, the underlying biology of which is poorly known, is the inability of communities to disperse propagules to new habitat, to respond to toxic chemicals, or in the case of simple communities, to exclude invaders". There is ample evidence to suggest that protection of mature, non-invaded habitats is an important element in the conservation of global biodiversity.

Plant invasions that alter ecosystem-level processes

Plant invasions that 'transform' or alter ecosystem-level processes are considered the most long lasting and damaging of all invasions (Ramakrishnan and Vitousek, 1989). On the North American continent, the conversion of the Great Basin sagebrush steppe ecosystem from a 60-year fire return interval, to a 5-year interval, with the subsequent decline of native species, has resulted from the widespread invasion of cheat grass, *Bromus tectorum*. Billings (1948) and Mack (1986) have chronicled the link between unsustainable cattle grazing in an ecosystem with no evolutionary association with large hoofed, congregating herbivores, and the collapse of the native bunchgrass community.

However, as noted earlier, two other events that have played a significant role in the collapse of the Great Basin ecosystem have not been acknowledged in any of the literature concerning biological invasions. Since the 1940s, millions of hectares throughout the region were sprayed repeatedly with the herbicides 2,4-D and 2,4,5-T to eradicate sagebrush (Ehrlich and Ehrlich, 1981), while at the same time alien grasses were planted widely to improve cattle forage on the range (USDA, 1965; McArthur, pers. comm.).

A small laboratory in Utah, the Shrub Sciences Laboratory, funded by the US Department of Agriculture, is currently engaged in an emergency effort to grow and plant native sagebrush for replanting in the intermountain region of the western United States. Nevertheless, in many places throughout the western US, publicly owned lands are still overgrazed, herbicides are still used to kill native shrubs, and alien grasses are still being planted (McArthur, USDA, pers. comm.).

These few examples illustrate the statement: "It may not be possible to separate the ecosystem level effects of biological invasions from the effects of the disturbance that created the invaded habitats in the first place" (Ramakrishnan and Vitousek, 1989). Efforts to mitigate the effects of invasive alien plants must address and mitigate these precipitating disturbance events, many of which are chronic, if they are to be successful.

It should also be recognized that nature does not permit the uncontrolled growth of any species, and populations typically become integrated into the community with little long-term

effects over time. A growing body of historical evidence suggests that human related invasions undergo four distinct phases: a latent or lag phase; rapid increase; decrease (occurs after a change in the human-related disturbance pattern); and finally, decline or extirpation (Groves, 1986). And while some species may undergo population expansion that appears threatening at the local temporal and spatial scale, it is important to remember that the native resident species have been exposed to a variety of environmental threats, including those that are extreme, over a period of thousands to millions of years.

Rate and scale of invasions today

An essential tenet of the claim that invasions represent an ecological emergency is that the rate and scale of invasion is unnatural and unparalleled (Vitousek *et al.,* 1997). Yet, this may be contradicted by historical evidence. In terms of rate and scale, the opening of the Suez Canal in 1869 was unprecedented, opening as it did the eastern Mediterranean to the Gulf of Suez on the Red Sea. As Williamson noted in 1996, no strong effects, extinctions, or community-wide patterns or cascade effects have yet been observed from the event. Vermeij (1991) studied the ecological effects of 12 biotic interchanges, which occur when two disjunct continents or bodies of water become connected and species are able to mingle and colonize new regions. The primary result is that areas with fewer species are more likely to accommodate new species – hence, they are enriched by the interchange. Webb (1991) found no evidence for cascade effects from historic interchanges, and instead found evidence for the widespread evolution of new species. Perhaps personal bias is to blame for our perceptions, which lead us to view population bursts as ecologically dangerous, particularly when characteristics usually reserved for disease pathogens or predatory species are attributed to plants.

In the San Francisco Bay, in California, approximately 100 aquatic species are classified as "cryptogenic," which means that their true origins are unknown (Carlton, 1996). Since their origins are unknown by scientists, no one knows whether they should be protected (native) or destroyed (non-native). Observing that native islanders considered most exotic plant species to be native in Puerto Rico, Ariel Lugo (1988) wrote, "There is no biological criterion on which to judge *a priori* the smaller or greater value of one species against that of another". This begs the question: what exactly is native? The answer is defined only by anthropocentrically biased time scales, and is often framed by which particular bias – usually economic – alters the perception of the observer.

Conclusions

Pesticide manufacturers have recently promoted the message that biological invasions are not hopeless, and that because of the arsenal of chemical pesticides available, those of us interested in protecting biodiversity can rest easy, with the knowledge that there is "hope". This message of hope is repeated frequently through industry advertising campaigns. The idea most frequently stated is that resource managers need not stand by idly while exotic species spread across landscapes, and that something can be done to preserve resident plant communities: buy and use more of their poisons.

I have also tried to offer a message of hope, by illuminating a partial sketch of the "other" side of plant invasions, one that suggests that invasive species may not be as great a threat to global biodiversity as has been suggested. This view places faith in the ability of the Earth to respond to changing conditions, but also asks more of us in terms of protection of habitats and restoration or reintroduction of native species. We must find ways to restore historical disturbance regimes, such as fire, and sustainable land use, where we want historical plant communities to thrive. Acting with the Native American concept of balance, we must assist the Earth in this process, because continuous injury to the Earth's ecosystems is not sustainable. By

listening to the Earth, we may be able to successfully assist in the healing of our home. If we continue to view invasions with a war-like mentality, however, we will be consigned to make war on nature indefinitely – until nature wins.

It is my hope that agronomic bias will not continue to dominate the development of solutions to the problems of plant invasions. Ecology-based solutions are not only necessary from the point of view of conservation, but are indispensable to any long-term and effective adaptation to changing conditions.

Kudzu's invasion into Southern United States life and culture

Richard J. Blaustein

… Up telephone poles,

Which rear, half out of leafage
As though they would shriek,
Like things smothered by their own
Green, mindless, unkillable ghosts.
In Georgia, the legend says
That you must close your windows

At night to keep it out of the house.
The glass is tinged with green, even so,

As the tendrils crawl over the fields.
The night the Kudzu has
Your pasture, you sleep like the dead.
Silence has grown Oriental
And you cannot step upon the ground ...

James Dickey "ALL:Kudzu"

Abstract

Kudzu, a perennial vine native to Japan and China, was first introduced into the USA in 1876 and was actively promoted by the government as a "wonderplant". It expanded to cover over 1 million ha by 1946 and well over 2 million ha today. When Kudzu invades a forest, it prevents the growth of young hardwoods and kills off other plants. Kudzu causes damage to powerlines, and even overwhelms homes. Kudzu has invaded important protected areas, requiring significant investment of management resources. The management response to date outside the protected areas has been insufficient to deal with this very significant threat.

Introduction

The Kudzu plant (*Pueraria lobata*) is an invasive alien species that has penetrated and persisted in the South-eastern United States for most of the twentieth century, and continues to debilitate natural communities and human well-being at the beginning of the twenty-first century. In fact, Kudzu has pervaded Southern life to such an extent that for many it has become a distinct emblem of the South. References to Kudzu abound in folklore, music, literature, advertising,

and Southern popular culture, testifying to Kudzu's invasion of the individual psyche and the collective ethos of the South. Many of these cultural responses to Kudzu employ humour or irony, or simply express the sense of resignation and acceptance with which individuals and communities often regard Kudzu.

Even as it embeds itself ever deeper in the Southern psyche, Kudzu continues to wreak intolerable damage to the South's natural landscape, human health, private property, commercial life, and enjoyment of public lands. As conservationists and land managers fight a continuous, and often losing, battle to halt Kudzu's march across the landscape, others not involved in the fight mistake Kudzu's invasion and degradation of lands and spaces as a natural process, and mistake the luxurious green shroud in which it smothers the land as the sign of a healthy and thriving ecosystem.

This paper examines the human dimensions of the ecological invasion of Kudzu. It begins with a brief description of the Kudzu plant and its invasive properties, followed by a historical sketch of Kudzu's introduction and diffusion throughout the South. Next, it examines Kudzu's effect on both the physical and cultural landscapes, which have been tightly interwoven throughout the history of the South. I will close with a few suggestions regarding what we can do about Kudzu.

The Kudzu plant

Kudzu is a climbing, semi-woody, perennial vine in the pea family, native to Japan and China. Kudzu spreads by vine growth, rhizomes and seeds. In the right climatic conditions – such as those, unfortunately, prevailing in the South-eastern United States – Kudzu grows at dramatic rates. A single plant may grow as much as 20 metres in a season, at a rate of about 30cm per day. Its impressive vines are anchored by equally impressive roots, often "7 inches (18cm) or more in diameter, 6 feet (180cm) or more in length, and weighing as much as 400 pounds (180kg)."

Kudzu is a classic invader, preferring disturbed or degraded habitats where sunlight is abundant, such as forest edges, clearcut patches, abandoned fields and roadsides. Once it has taken root in a disturbed area, Kudzu can expand rapidly outward, covering surrounding plants with a luxurious green foliage that blocks access to sunlight and, over time, crushes competitors beneath its weight. Once established in an area, Kudzu begins to reshape the entire landscape, enshrouding and slowly killing surrounding fields and forests, and destroying habitat for associated wildlife.

The introduction of Kudzu into the South-Eastern United States

Kudzu was first introduced into the United States in 1876 at the United States Centennial Exposition in Philadelphia, Pennsylvania, where a bazaar was built to house a plant exhibition from Japan. At this Pavilion, Kudzu received noted attendee admiration (Kinbacher, 2000), with one admirer writing to her sister in Florida: "Today I visited the Exposition. Of all the marvellous things there, a vine which the Japanese call Kuzu (*sic)* astounded me the most...Knowing how you suffer from that awful heat down there, I am going to try to get one of the vines for you" (Hoots and Baldwin, 1996). This comment illustrates one of the primary attractions of Kudzu for Southerners, namely its provision of shade.

Shortly after the Centennial Exposition, Kudzu was brought directly to the South during the New Orleans exposition in 1883. During these final years of the 19th century, Kudzu introductions into Southern communities were not as pernicious as they would later be, because it was "first used as an ornamental vine to shade porches and courtyards" (Miller, pers. comm.)

and because the Kudzu "was supported by some type of trellis...inhibit[ing] normal reproduction through runners putting down roots from nodes" (Hoots and Baldwin, 1996).

By the early twentieth century, however, Kudzu was being enthusiastically used for purposes other than residential ornamentation, bringing vines into closer contact with the land and encouraging the Kudzu to take root and expand. For example, in the first decade of the twentieth century Kudzu was used as a fall-back feed for inexpensive livestock foraging in locales of over-grazed pasture (Miller, pers. comm.).

In the early decades of the twentieth century, charismatic and zealous promoters brought Kudzu to prominence as a "wonder plant." In Florida, for example, Charles and Lillie Pleas established the Glen Arden Nursery to grow and market Kudzu, "a miracle vine they should use to help humankind" (Hoots and Baldwin, 1996). In Georgia, radio personality Channing Cope used his daily radio programme to extol the many virtues and uses of the plant. Cope also founded the Kudzu Club of America, which putatively had 20,000 members who met "to promote planting Kudzu" (Hoots and Baldwin, 1996).

The growing cult of Kudzu was buttressed by commercial enterprises interested in expanding the plant's use. In 1920, for example, the Central of Georgia Railroad distributed free Kudzu plants to farmers with the hope that the farmers would grow Kudzu hay – a profitable crop at the time – and then transport it on the railroad (Kinbacher, 2000; Hoots and Baldwin, 1996).

Kudzu's most effective proponent by far, however, was the United States government. In the 1930s, massive soil erosion on Southern farmlands compounded the local impact of the Great Depression, seriously threatening the region's agricultural base. To bring the erosion under control, the federal government launched a massive promotional campaign for Kudzu. Throughout the 1930s and 1940s, the Soil Erosion Service and its successor, the Soil Conservation Service, touted Kudzu as the remedy to the South's soil problems. In a little more than a decade, these agencies provided "about 84 million Kudzu seedlings...to southern landowners for erosion control and land revitalization..[and it] offered up to $20 per ha as an incentive for farmers to plant their land in Kudzu" (Miller, pers. comm.). The acreage planted in Kudzu rose from an estimated 4,000ha in 1934 to 1.2 million ha by 1946.

In a few years time, farmers became very concerned about the noticeable invasive and disruptive characteristics of Kudzu. Kudzu's uncontrollable growth, its smothering of pine trees, and other problems (combined with the emergence of new agricultural methods to mitigate erosion) led to a massive – but glacially paced – reassessment of Kudzu's value by both the U.S. government and the agricultural community. In 1953, the United States Department of Agriculture (USDA) removed Kudzu from the list of cover plants permissible under the Agricultural Conservation Program. By 1970, USDA had identified Kudzu as a common weed. And in 1997, after more than half a century of mounting evidence of its harmfulness, Kudzu was finally listed as a "noxious weed" under the Federal Noxious Weed Law.

Kudzu and the natural landscape

The damage done by Kudzu to the natural landscape in the South-eastern United States is enormous. Religious metaphors comparing the Kudzu invasion to biblical scourges are apt and appropriately evocative of the degradation the plant has visited upon the ecosystems of the South. By the mid-nineties it was estimated the Kudzu "has a stranglehold on an estimated 2.8 million ha and is spreading by 50,000ha a year and is increasing." The total area infested by Kudzu is larger than the state of Vermont, with the heaviest infestations of Kudzu occurring in Alabama, Georgia, and Mississippi. Although most Kudzu is found in the Southeast, recent sightings have been made as far north as Massachusetts and as far west as Texas and Oklahoma.

The impact of Kudzu on the Southern landscape is especially pernicious because of the high levels of biodiversity and endemism found in South-eastern states. During the last ice age, the

Southeast served as a refuge for species retreating from the southern-bound glacial advance that reached its maximum 18,000 years ago (Stein, Kutner, and Adams, 2000). The South retains relict populations of many species that were pushed out of the Upper Midwest and Northeast by the advancing ice (Stein, Kutner, and Adams, 2000). As a result, the South enjoys levels of plant diversity and endemism second only to the (much larger) western states.

Kudzu poses a significant threat to this diversity. Indeed, the threat of homogenization has already been realized in many locales as"[s]pecies rich forest ...with their associated wildlife, recreation and aesthetic values are being replaced with a smothering matter vine monoculture" (Miller, pers. Comm.). Kudzu diffuses throughout the forest ground and inhibits the natural process of tree renewal, preventing the growth of young hardwoods and killing off other plants. Kudzu out-competes brush and indigenous plants, which in turn diminishes vital food and habitat resources for wildlife. The only plant species that successfully compete – and co-exist – with Kudzu are other invasive aliens, such as Chinese privet and Japanese honeysuckle. Together, they are reducing once-rich ecosystems to impoverished – if deceptively lush – vine barrens.

This degradation of the natural landscape is a profound loss for the South, and will be a cause of enduring grief if it is not reversed. The Southern culture's vital relationship with the landscape has been known and felt throughout American history, and is the basis for pride and accomplishment in literature, music, and civic spirit. In fact, it may be said that the biodiversity of the South has served as a primordial force shaping the human sense of freedom and of attachments. William Bartram, who with his father John were the seminal American naturalists in the eighteenth century, evoked this primordial connection of man to landscape in the South when he wrote of his explorations of the natural landscape around the Mississippi river in what today would be East Baton Rouge Parish, Louisiana. As Bartram noted, "the trees, high forests, even every particular object, as well as societies, bear the stamp of superiority and excellence; all unite or combine in exhibiting a prospect of the grand sublime" (Torrance, 1998). Almost a century and a half later, the Nobel prize-winning novelist and Mississippi resident, William Faulkner, would echo Bartram's appreciation of the natural bounty of the Southern landscape, an example of which is the following passage from the novella, "The Bear":

> ...He had created them, upon this land this South for which He had done so much with woods for game and streams for fish and deep rich soil for seed and lush springs to sprout it and long summers to mature it and serene falls to harvest it and short winters for men and animals... (Faulkner, 1973).

Beyond the writing worlds of Bartram and Faulkner, subsequent writers and laypersons have also been inspired by the Southern landscape's "grand sublime", of which Kudzu, followed by other invasive alien species, may impede or even deprive their descendants from encountering in the future.

Kudzu and southern culture

Kudzu has so altered the southern landscape and human experience within it that it has "seeped into southern culture" (Kinbacher, 2000) and established itself as a constant in the youth, adulthood, and old age of the individual. Indeed, the apparent inevitability of Kudzu in southern life has led many to resign themselves to the invasive species and to respond with humour, irony, or even a romanticized hopelessness. By the mid-1980s, for example, "[s]ociologists note a period of tempered enthusiasm for the vine...During this period total eradication of Kudzu became increasingly unlikely, and southerners began to reconcile themselves to the plant" (Kinbacher, 2000).

As a part of this reconciliation to Kudzu, the coping response of humour became pervasive, which is first evidenced in the many names and phrases used to refer to Kudzu. In addition to

the well-circulated reference, "the vine that ate the south", other names for Kudzu include "drop it and run vine", "mile a minute vine", "Sodom vine" and "typical government gift" (Hoots and Baldwin, 1996). Humour as an expression of resignation or inevitability is also seen in the southern music scene where musical groups sing of Kudzu and sometimes have Kudzu in their names. The Kudzu Kings, the Kudzu Quartet, and the Kudzu Krooners have, in addition to Kudzu in their names, all a resemblance of Kudzu in their visual logos (Kinbacher, 2000). With the punk rock group, Kudzu Ganja, the Kudzu in the band's name and its presence in their logo intertwined with marijuana serve as an emblem of the nihilism and disenchantment the band explores in their music (Kinbacher, 2000).

Using Kudzu in crafts is another example of Kudzu's seeping into southern culture, and the culture's responding to a seeming inevitability with a temporary coping response. A well circulated book, Diane Hoots and Juanita Baldwin's *Kudzu: The Vine to Love or Hate,* is dedicated to the craft usages of Kudzu. The book has numerous instructions as to basket-weaving, paper making, and recipes, as well as mentioning Kudzu crafts festivals and events. Notwithstanding the upbeat instructions found in the book, the title of Part IV, "Making the Best of the Kudzu Predicament" (Hoots and Baldwin, 1996), alludes to the seriousness of Kudzu infestation, and underscores the fact that material usage of Kudzu should be seen as a temporary measure to keep up morale and use up some Kudzu. As the authors of the book say in their final segment:

> Kudzu has covered 7,000,000 acres (2.8 million ha) of land in the Southeast. Unless a way is found to stop it, this figure will double in ten years... The debate is over. Kudzu is changing ecosystems as small as freshwater ponds, a homestead, roadside, or huge slices of a county or state. Even those who recognize and promote the usefulness of Kudzu agree ... (Hoots and Baldwin, 1996).

Even with the attraction of craft possibilities, any responsible means of using and coping with Kudzu warrants a continuous awareness of the plant's damaging reality and potential.

A final example here of Kudzu's "seeping into southern culture" is the plant's evocative presence in literature and folklore. Here, the ominous nature of the Kudzu threat is not lost on talented and nature-appreciating writers and good folklore storytellers. Interestingly, the conveyance of the threat of Kudzu often associates Kudzu with the perils of snakes. In the above-quoted poem by James Dickey, for example, the poem proceeds to depict the intertwining menace of snakes and Kudzu. As Dickey writes:

> For when the Kudzu comes,
>
> The snakes do, and weave themselves
> Among its lengthening vines
> Their spade heads resting on leaves,
> Growing also, in earthly power
> And the huge circumstance of
> Concealment.
> One by one the cows stumble in,
> Drooling a hot green froth,
> And die …
>
> (Dickey, n.d.).

Numerous anecdotes, most often unverified, abound with tales of snakes launching perilous surprises in the Kudzu vine. In addition to the snakes and Kudzu, the rapid 30cm-a-day growth rate and the audibility of its growth add to a folklore of ominousness and menace that may serve as a counter-balance to a sentimentality or an abandon of seriousness that can arise in response to Kudzu.

Kudzu's interference with commercial life and human well being

Kudzu's impact on human commerce and human health might seem to be two topics warranting separate discussion. However, as Kudzu's main impairment of human health is its production of widespread stress (Miller, pers. comm., 2000) and as its inducement of this stress is inextricably linked to the invasive species' burden on property ownership and usage, discussing commerce and health together best conveys the invasive mode of Kudzu.

Kudzu's economic impact is enormous. One recent U.S. government publication estimates Kudzu causing over US$100 million of damage a year. Another source, which factors in US$336 million of lost productivity in forests, estimates total productivity losses to Kudzu as "greater than $500 million per year" (Miller, 2000).

Two examples of Kudzu damage occurring in vital economic sectors are in railroad service and the power industry. With the railroad business, Kudzu presents engineers with unexpected dangers on what expectedly would be safe runs. Train wheels passing over Kudzu cause a slick pulp to form on the rails, and these often lead to dangerous slipping and occasional derailments (Hoots and Baldwin, 1996). Railroad companies have had to respond to Kudzu with extra resources and manpower devoted to clear Kudzu from rails.

Likewise, power service has notably been interrupted across the South, especially in rural areas, due to Kudzu spread. In the South Kudzu often climbs up the guy (wire and pole supporter) and either weaves into the hot wire or causes the pole to fall, causing a cut in the power supply. In one substantial area of Alabama, it is estimated that the Alabama Power Company has to devote at least some summer hours from 100 of its employees to clearing Kudzu from power lines or their supports (Zarichnak, pers. comm., 2000). In total, a reasonable figure of US$1.5 million per year is assumed by power companies in the South for removing Kudzu from or around power lines (Miller, 2000).

The most conspicuous Kudzu burden is on property owners and the use of their land. Because of Kudzu infiltration, farms are often degraded beyond use, and homes are, literally, overwhelmed by the Kudzu affliction. Ensuing from this Kudzu invasion great stress is experienced by individuals whose homes and farms have been swarmed by Kudzu. One expert believes that, pursuant to his own response to complaints, thousands of homeowners have been subjected to great stress resulting from Kudzu encroaching on their homes (Miller, 2000). In addition, many people have complained about being deceived and losing money after paying so-called "Kudzu specialists" considerable sums to remove Kudzu from their property, to no avail. The following poignant example is recounted by Dr. James Miller, a leading expert on Kudzu with the U.S. Department of Agriculture, as he recalls a letter he received from an elderly lady: "She related that Kudzu surrounded her home in the country, and her husband had fought it back until he had passed away a few years before, and now she was unable to keep up the fight. She told of her horrible recurring nightmares of Kudzu coming through the windows at night and grabbing her" (Hoots and Baldwin, 1996).

Numerous others have suffered emotionally and physically from Kudzu invasions on their private property. When adding the enormous human stress caused by Kudzu to similarly-caused respiratory ailments, allergies, and other physical maladies, Kudzu's effect upon human well-being can best be viewed as a profound impairment.

Kudzu's invasion of the national park system in the South

During the interruption of government services and access in the 1995/1996 winter – i.e. the government shutdown – many politicians and journalists were very surprised by the American public's outrage regarding its denied access to national parks (Mitchell and Olson, 2000). Indeed, these politicians and commentators soon learned that for many in the United States the national parks are cherished public places, and these Americans insist upon access and upkeep of their national parks.

In the American South these parks are no less valued than in any other part of the United States. In fact, in the South these protected lands are often also the sites of historic civil war battles, and these historic connections interweave historical sentiments with the human experience of nature in a very evocative fashion. Unfortunately, at these unique southern national parks, Kudzu infiltrates ecosystems and often hinders the full human experiencing of nature and history. Three examples in the South where Kudzu is a major concern of the individual park management, the national park system, and the general public visiting the parks are Vicksburg National Military Park, Chickamauga and Chattanooga National Military Park, and the Great Smoky Mountains National Park.

Vicksburg National Military Park, located in Mississippi, was the site of fierce battles from 29 March to 4 July 1863. Vicksburg was perched on high bluffs (many of whose natural and essential grasses are now displaced or threatened by Kudzu), and was known as "the Gibraltar of the Confederacy." When Vicksburg surrendered, its fall, along with the fall of Port Hudson, Louisiana, divided the South, and gave the North undisputed control of the Mississippi river.

Today Vicksburg is the site of a national park consisting of 760ha, of which 80ha are either threatened or invaded by Kudzu. Four ha of Kudzu-infested park have been treated with fire and herbicide, but in the many other areas under threat or already invaded by Kudzu, the situation is indeed dismaying. In these areas Kudzu prevents tree growth and imperils the trees standing. In Vicksburg if these trees are felled the surrounding vistas made up of substantial commercial development would intrude upon the park, undermining the historical evocation of the civil war battles to the great dismay of park employees and visitors (Nichols, pers. comm., 2000). In another part of the park, Kudzu threatens the strategic bluffs, which were an intrinsic part of the Vicksburg fortress arrangement and which were covered with natural grasses. In these places and in the forested parts, the strategy of Kudzu eradication that was employed on four ha would not be appropriate. At present Kudzu not only threatens the park landscape but also has succeeded in causing pessimism and grief over the future of a highly valued piece of natural and historical heritage.

The situation resulting from the presence of Kudzu at Chickamauga and Chattanooga National Military Park, located in Georgia and Tennessee, is not as dire as that of Vicksburg, but is still a cause of concern. The prize for the battle at this site was Chattanooga, Tennessee, which was the key rail centre and gateway to the heart of the Confederacy. After many months of a vicissitudinous series of battles, the Union forces captured the area. This region would later serve as the launching base for General Sherman's famous conquering of Georgia.

Today the Chickamauga and Chattanooga National Park consists of seventeen disconnected pieces covering 2,000ha, and is adjoined by the 1,120ha of Lookout Mountain, which has some public land belonging to the national park. From 1992 to 1998 a sustained effort to control Kudzu at the Chickamauga locales was executed, and this effort has been deemed a success as native grasses resumed their places in the ecosystem (Weddle, pers. comm., 2000). On and around Lookout Mountain the situation is different. Lookout Mountain is a mixture of public and private lands. On Lookout Mountain's public lands, the government actively and successfully fights to control Kudzu, but on private lands many owners are indifferent and take

no measures against Kudzu. These private sites serve as a base from which Kudzu threatens public spaces.

The Park Service management mentions that as yet no ground swell of interest for remedying the Kudzu situation on private lands has appeared, and this prevents a holistic private/public initiative to control Kudzu. In this locale, Kudzu benefits from the lack of coordination between private and public property owners.

The Great Smoky Mountains National Park is unlike Vicksburg and Chickamauga parks, not solely because it does not commemorate a battle, but significantly because it is one southern national park where Kudzu is successfully controlled. At the Smoky Mountains National Park, located in Tennessee and North Carolina, the success in controlling Kudzu is due primarily to the fact that the park has worked on the Kudzu threat for over 60 years, dedicating a considerable amount of resources and employee time to the Kudzu problem. Of the 120 Kudzu sites in the park in 1990 only one site now experiences uncontrollable Kudzu. This site is at a foothill adjacent to a prospective road development, and the park therefore has decided that it is not detrimental to the other parts of the park and will be contained, if not eradicated, in the future (Johnson, pers. comm., 2000).

It is fortunate that the Great Smoky Mountains National Park has had success with their sustained efforts directed against Kudzu, because one estimate has it that the Kudzu invasion of the park would have covered up to 20% of park lands with its monoculture if the effort had not been sustained (Johnson, pers. comm., 2000). Thus, Kudzu has required a 60-year effort to prevent it from robbing the public of enjoying the Great Smoky Mountains National Park.

Conclusions

Kudzu has infiltrated the South, pervaded the culture, altered lifestyles, caused great distress, and hindered the enjoyment of national parks. Significantly, many of those who either work on or have studied Kudzu do not believe the current combination of responses will control the problem. These individuals often hope that in the future an effective biocontrol programme will be developed and implemented that will finally bring the Kudzu problem under control (Miller, 2000).

In the meantime education and an increase in resources dedicated to the problem could lead to a better handling of Kudzu. In areas where public lands border private property where owners are insufficiently engaged in controlling Kudzu, the government should direct funds to develop public outreach programmes that would take the lead in coordinating private and public interests and responses. Also, the federal, state, and local governments should devote more resources to helping people who are overwhelmed by Kudzu infestations. These government efforts should include centres and sources that would provide people with information about legitimate Kudzu redresses and their agents. Finally, there needs to be more awareness that Kudzu causes much hardship and losses to human beings, and that any coping response to Kudzu should never drift into resignation or an embrace of the plant that causes such distress to human beings.

Human dimensions in the management of invasive species in New Zealand

C.R. Veitch and M.N. Clout

Abstract

New Zealand has been only recently populated by humans, but thousands of species of plants and animals have been introduced, with nearly 700 of them now considered to be pest or weed species. Strong legislation exists to limit new introductions and to enable control of existing infestations. Attitudes to invasive alien species vary between different public groups and between different groups of species, tempered by management costs and by official policies. Public perceptions of invasive species come either from direct experience of impacts of these species or from the media and other sources of information.

Introduction

Knowledge of the pre-human condition of New Zealand has an important bearing on an appreciation of the subsequent impact of introduced species, particularly the perception of whether they are invasive or benign. Before human settlement the country was mainly a forested land, with bats as the only land mammals. Forest originally covered about 80% of the land but by the time of European arrival that was reduced to about 53% and today comprises about 21.6% of the land cover (Cumberland, 1966).

The Pacific rat (*Rattus exulans*) was the first invasive species introduced to New Zealand, probably around AD 50–150, during transient visits by Polynesian visitors. These alien mammals did not reach offshore and outlying islands until after permanent Polynesian settlement of the country occurred, around AD 1300 (Holdaway, 1999). Circumstantial evidence indicates that the Pacific rat, alone, caused extinction or depletion of several bird, lizard and insect species, and significant modification of floral assemblages (Holdaway, 1989).

The first European contact with New Zealand was that of Captain James Cook in 1769. From then onwards many plants and animals were deliberately and accidentally introduced to the country. Colonists from the United Kingdom brought with them, or later imported, a huge array of species to make the land "more like home".

From the early 1860s "Acclimatisation Societies" were established in New Zealand to promote the introduction of exotic animals for hunting, and plants for propagation to supplement existing vegetables, fruits, flowers and shrubs (McDowall, 1994). Major reasons for the introductions were nostalgia – a desire to be reminded of Britain, from which the settlers had emigrated – and sport – mammals and birds that could be hunted. In addition to these formally "planned" introductions, many other species (especially plants) were brought to New Zealand by colonists during the nineteenth and twentieth centuries. Hundreds of species of plants, birds and mammals were introduced, many of which became established.

As a result of this massive surge of deliberate introductions, and some accidental ones such as mice (*Mus musculus*), Norway rats (*Rattus norvegicus*) and ship rats (*R. rattus*), the fauna and flora of New Zealand has been transformed (Table 1).

Table 1 The numbers of species introduced to New Zealand and their present status.

Group	Number introduced	Number established	Number of pests
Vascular land plants	18,830	2020	>300
Freshwater plants	191	52	8
Seaweeds	?	20	1
Terrestrial mammals	55	32	28
Freshwater fish	?	19	9
Birds	145	36	6
Frogs and reptiles	?	4	0
Insects	?	?	>350

"Number introduced" is species known to have been imported to New Zealand. "Number established" is species now with self-sustaining wild populations. "Number of pests" is species which are now listed in legislation or policy documents as pests or weeds, or which are under some form of control to reduce their numbers.

(After Buddenhagen *et al.,* 1998; Hackwell and Bertram, 1999; King, 1990; McDowall, 1990; Owen, 1997; Veltman *et al.,* 1996; Williams, 1997; C. J. Green, pers. comm.)

Invasive species legislation

Border controls, as a tax regime, were instigated with early European settlement and became one of the first New Zealand laws in 1841. Border control actions to manage the importation of animals and plants began in 1894.

Plants were first legally recognized as weeds in the Orchard and Garden Pests Act of 1896. The species listed in this Act, and subsequent noxious weeds acts, were plants which were agricultural pests and it was not until the Noxious Plants Act of 1978 came into being that plants which were invasive in natural environments were recognized. These Acts all required that land owners and occupiers took full responsibility for managing the listed species on, and adjacent to, their holdings. More than 80 species were listed as Noxious Plants.

The Noxious Animals Act of 1956 related to a number of pest animal species but, unlike the Noxious Plants Act, was largely a measure to allow animal control staff to enter onto private land to hunt pest animals.

Other Acts related to individual or select groups of species, or to specific actions in relation to a wide range of species. For example, the Wildlife Act 1953 made it illegal for any person to liberate any wildlife, including species which were not otherwise protected by law.

The Biosecurity Act of 1993 replaced most of the previous pest control acts and remains in force today. It requires the management of pest species to be directed by "strategies" which are drawn up with a prescribed public process. As a result there are a few national strategies, e.g. bovine tuberculosis, and each Region Council has drawn up one or more strategies for plants and animals within their region. These strategies may require Region Council staff or landowners or members of the public to take pest control actions. While there are a number of

significant pest species that are listed in most strategies, the actions to be taken and the other pest species included differ considerably from region to region.

The public

There is no such thing as a single public perception of invasive species, but here are groups within New Zealand society who have differing views of these species.

Maori: Maori people, as the first human inhabitants of New Zealand, have a special place in law and policies relating to invasive species. Although frequently ignored by Governments in the past, local Maori tribes (*iwi*) often hold strong views on the management of pests and weeds within their area and are now routinely consulted over plans to control or eradicate invasive species. Although there is no single Maori perspective on invasive species, common concerns of several *iwi* are the use of toxins, effects on harvestable wildlife, potential for pollution of water supplies, and the introduction of new species for biological control.

The rural community: Farmers have a long history of action taken to control pest animals and weeds considered to be detrimental to their rural activities (agriculture, horticulture etc.). In the past, most farmers converted natural environments such as forest and wetlands into pasture or croplands and took action to control any native or introduced species that were considered detrimental to production. More recently sectors of the rural community have come to recognize natural values.

The urban community: The early urban population of New Zealand stemmed from a rural background or had a high dependence on the rural economy. Their perception of invasive species was therefore largely gained from the rural sector. More recently the urban population has come from other generations of urban dwellers. Their perception of invasive species has come from their peers, and public media. Many of these urban people are keen gardeners, using a wide array of introduced plants in their gardens.

The 'green' community: New Zealand has an increasingly strong group of people who are trying to maintain an ecologically friendly and sustainable lifestyle. They wish their environment to be free of both invasive species and of some of the methods commonly used to control them (e.g. accumulating toxins, genetically engineered diseases).

Animal rights lobbyists: New Zealand has a relatively small, but growing, group of people who are especially concerned about the methods used to control animal pests and demand that these control measures are humane. Most concern currently focuses on the control of introduced mammals (e.g. feral horses, see later).

Don't care: A large section of the community does not care (or know) about invasive species and may feel that no aspects of their lives are affected by such species.

The invasive species

Invasive species themselves may also be grouped, not taxonomically but by the ways in which they are viewed by the public.

Hated invasives: Some invasive species are almost universally disliked. These include some mammals (e.g. rodents, possums) and some plants (e.g. *Ulex europaeus, Clematis vitalba*) that are widely recognized as being undesirable. Potential invasives such as snakes and scorpions also fall into this category.

Attractive invasives: Domestic mammals (e.g. cats, horses), and some birds are viewed by many people as warranting special consideration, even when they are feral and ecologically damaging, because people empathize with them. Invasive plants with pretty flowers or leaf forms are the botanical equivalent: people find them attractive and often ignore their invasive nature (e.g. lupins invading braided riverbeds in the South Island).

Crop, livestock and pasture pests: These pests are usually recognized by only the farmer. Crop weeds and insect pests are the most common, but birds and rodents can also have an effect on crops and pastures, and some mammalian pests can carry livestock diseases.

Sporting species: Animal species which can be hunted or fished for sport, or because they are edible, are fervently protected by those who do the hunting and fishing, or who sit in an armchair dreaming about it. In New Zealand some of these animals are native (e.g. some waterfowl), but many are introduced mammals (e.g. deer) or fish (e.g. salmonids).

"Benign" species: Many alien species are generally considered to be benign. They include small, insignificant, plants, fish that are rarely seen, or insects that "are surely too small to be damaging".

Causes of perception

The first factor which causes people to consider a species to be an invasive pest is probably damage to property. This may take the form of weeds in a crop, insects eating a crop, rodents eating stored food, and many similar examples. People have been working to improve crops, pasture and stored foods by controlling invasive species for many years. This, in turn, has led to a dislike of some species regardless of where they are or what they are doing, notably most rodent species. But the dislike of rodents, in this example, is tempered by the fact that some children will keep rats or mice as pets and present-day houses are largely rodent-proof. This means that mice may be quite acceptable occupants of a suburban garden shed.

Damage to natural ecosystems by invasive species have often been less visible to the public. Often changes have been slow or inadequately recorded to show the change. However, the more visible changes brought to natural ecosystems by invasive species, such as native trees killed by browsing brushtail possums (*Trichosurus vulpecula*) or overtopped by old man's beard (*Clematis vitalba*), have dramatically demonstrated to the public that invasive species are present and causing damage. With such knowledge in mind, the public are also able to perceive damage by invasive species that occurs on a less visible scale.

The shape, size, colour and general "appeal" of a species, whether it is invasive or not, can seriously influence public perception. For example spiders and wetas (large flightless crickets) have no detrimental impacts, but are nevertheless generally disliked.

Some people will like or dislike a species simply because another person has told them it is good or bad and they wish to accept the opinion of that person. In this way a person in a position of power, or with a charismatic nature, can influence the public perception without giving them facts.

Media portrayal can have a significant influence on public perception. If the media choose to leave out one side of a discussion, or simply emphasize a point of view, then many people will accept that as the correct situation.

The cost of managing a pest species will be a significant part of a decision-making process about pest management. While this is usually not visible to the public, they can influence a decision if they are made aware of a significant cost.

If the public sees detrimental impacts from a proposed pest management method, then they may well demand that the management method be modified or the entire programme stopped.

Changes of public perception over time

Over the past half century the public perception of invasive species in New Zealand has changed notably. The population structure of the country has changed significantly with the emergence of an urban population, which has a limited relationship to the rural economy and to historical rural attitudes to invasive species. The invasive species knowledge of the urban

population is based largely on information gained from the media that are available within the urban community.

The volume of information, both fact and fiction, about the ongoing effects of invasive species and their management has been increasing. This information is about both the benefits and detriments of both the species being controlled and the methods used for that control.

Some examples

1. *Border control.* For many years New Zealand has had laws and a strong will to control invasive pests at border control points. People entering the country are not permitted to bring a wide array of produce, seeds and other items into the country. Recent changes in global transport and travel, and political willpower, have seriously eroded the ability to keep invasive species out of the country. Today, due to financial constraints on border control staff, just one in five of the shipping containers entering the country can be checked for pests, so containers from "high risk" areas are identified and checked first. People arriving by air are advised of the pest risks but New Zealand's national carrier, Air New Zealand, refuses to show passengers a video prepared by border control officers on this subject. Other airlines do show this video. At the border, queues are inevitable and passengers complain if they believe they are being unduly delayed. Often these complaints are aired in the media and taken heed of by politicians. The need to stop pests entering the country is of secondary importance to many people.
2. *Rabbits.* The best known of the early European introductions is the rabbit (*Oryctolagus cuniculus*). Captain Cook released some in 1777 (Gibb and Williams, 1990) which failed to establish, as did other liberations between 1840 and 1860. Liberations between 1860 and 1869 did establish, but the scale of this mistake was rapidly realized as rabbits became a major invasive pest, and one of the first to be subject to control attempts and associated legislation. Rabbits were reported as a nuisance in Southland and Marlborough in 1869 (Miers, 1970) and were recognized by Government in the Rabbit Nuisance Act of 1882. Control of rabbits over the past 120 years has involved large scale shooting, trapping and poisoning. It has also involved at least three attempts at biological control. The first was the introduction of mustelids (stoats, weasels, ferrets) in the 1880s, the second was the failed attempt to introduce myxomatosis in the 1950s (appropriate vectors were absent) and the third was the illegal introduction and distribution of rabbit calicivirus disease (RCD) by farmers in 1997. This followed a Government decision to defer the introduction of this new disease, which had recently escaped from containment in Australia. Pastoral farmers in rabbit-infested parts of the South Island were incensed at this decision and some took things into their own hands, apparently smuggling in the virus from Australia and distributing it widely. By the time it was detected by officials it was too late to eradicate it. Owners of pet rabbits were concerned about infection and conservationists were concerned about the effects on native wildlife of prey-switching by mustelids and cats. The RCD introduction is an example of a special interest group bypassing due process and border control laws in their own interests. Paradoxically, these border control laws are in place primarily to protect the interests of the agricultural sector.
3. *Brushtail possums*. The brushtail possum (*Trichosurus vulpecula*), an Australian marsupial, is a recognized pest species throughout most of New Zealand. It damages forest, preys on the nests of native birds and carries bovine tuberculosis. Various methods (trapping, poisoning, biological control) are used or proposed for possum control and there is some form of opposition to almost all methods. There is especially strong opposition from some in the hunting community to the widespread aerial distribution of baits containing 1080 poison (sodium monofluoroacetate), because this poison also kills wild deer and feral pigs and is highly toxic to dogs that may scavenge on

carcasses. More general public opposition is weaker, often involving just a general concern about the need to use poisons and questions about the safety of 1080, especially when broadcast in areas frequented by the public, or in water catchment areas. Good public information strategies can help allay the latter fears. The Hunua Ranges, south east of Auckland City, supply about 60% of the water needs for Auckland and they also have possums, which damage forests, prey on native birdlife can carry disease, and require control. It was proposed to aerially spread 1080 poison in pollard pellets. After a two year period of information dissemination and consultation this work was successfully carried out. A few years later a similar operation was proposed for a large forest area in Northland. This was not a water supply area, but there was significant protest action from people living in the area and their banners and media statements opposed the use of 1080 poison to kill the possums, asking that control be done by trapping instead, to provide local employment. At that time the trapping option was judged to be some four times more expensive than an aerial spread of poison. After consultation, the aerial poisoning operation went ahead and was accepted by the majority of the public.

4. *Rats.* The Pacific rat (*kiore*) (*Rattus exulans*), was one of the earliest human-assisted introductions to New Zealand (Holdaway 1999). Like all other rodent introductions to rodent-free lands, this rat has had a significant impact on the flora and fauna of New Zealand (e.g. Atkinson and Moller, 1990; Campbell, 1978). The changes caused by this small rodent (adult male maximum 100g) were relatively slow and it is only recently that studies have demonstrated the degree of damage. Recently, it has proved possible to eradicate rodents from islands, using poison baits. On hearing of proposals to eradicate Pacific rats from islands, some Maori leaders have spoken strongly against such eradications. They have stated that the Pacific rat or *kiore* is a *taonga* (a treasure), brought to New Zealand by their ancestors in the course of their migrations. Some scientists supported the proposed eradications, but others opposed them because they believed that there was inadequate scientific proof of the detrimental impacts of this rat. The law requires that Maori at the local tribal (*iwi*) level be consulted before any such pest management actions are taken. In every instance where local *iwi* have been fully consulted and involved in decisions on the removal of Pacific rats from islands, they have agreed to the action.
5. *Kaimanawa horses.* In New Zealand a herd of feral horses has inhabited the Kaimanawa area of the central North Island since the 1870s. Pressure from land development and hunting progressively reduced both numbers and range, so that by 1979 a census revealed only *c.*174 animals. Prior to 1981 there was no formal management of the horses, but in that year public lobbying resulted in the creation of a c.70,000ha protected area in the core range of the "Kaimanawa wild horse" herd. Under protection, the horses expanded their range beyond the protected area and increased to 1,576 animals by 1994, a population doubling time of approximately four years (Department of Conservation, 1995). In response to concerns about damage caused by the rapidly growing horse population to native plants and ecosystems (Rogers, 1991), a management plan was written (Department of Conservation, 1995). This recommended removal of the protected area, eradication of horses from 70% of their range, and management to retain a herd of *c.* 500 in the remaining range. Research was to be undertaken to determine critical thresholds for ecological damage and the feasibility of using immuno-contraception methods to reduce fertility. The management plan was accepted by the Department of Conservation, but there was then intense public lobbying by animal rights activists and horse enthusiasts against the shooting of horses. This resulted in a political decision in 1997 by the Minister of Conservation to muster as many horses as possible and to sell them to members of the public. This overturning of the management plan

effectively overruled the advice given to the government by the Department of Conservation. The muster and sale of several hundred horses duly took place. Unsold animals were slaughtered. The long-term fate of the Kaimanawa herd remains unresolved. This example shows the special importance of public opinion in the management of invasive species that have emotive appeal, and the potential for political decisions overriding ecological management priorities in such cases.

6. *The rainbow lorikeet*: The rainbow lorikeet (*Trichoglossus haematodus*), a brightly coloured gregarious parrot, native to parts of Australia, Indonesia, New Guinea and New Caledonia, became locally established in the 1990s in Auckland, New Zealand, following deliberate releases (Polkanov and Keeling, 2000). The eradication campaign against the rainbow lorikeets in Auckland was contentious and public opinion was divided. Many people could see no harm in having an attractive addition to the local avifauna, but many others considered that the potential risks to native birds were unacceptable. There was considerable local news coverage and Internet web pages became a publicity medium. The Department of Conservation (DOC) web page stated that rainbow lorikeets feed primarily on pollen, nectar and fruits, and rear up to three broods per season. It said that Australian horticulturists regard them as a significant pest, that in Darwin 80-90% of some tropical fruit crops are lost to rainbow lorikeets and that they could have a significant impact on New Zealand's horticulture industry. DOC claimed that Australian evidence, supported by observations in Auckland, is that these birds are generally aggressive towards and dominate all other birds trying to use the same food source. Native bird species which occur on island reserves in Auckland's Hauraki Gulf such as the *tui*, bellbird and *hihi* (stitchbird) use the same food sources, and could readily be displaced by a flock of lorikeets and there could be some competition for nest sites. Since lorikeets have been recorded travelling over twenty kilometres to Australian offshore islands, they may pose a significant threat to native birds on island sanctuaries near Auckland. The Rainbow Trust web page opposed removal of the lorikeets and said the claims made by the Department of Conservation against the rainbow lorikeet were either exaggerated or incorrect. They said that evidence suggests that the rainbow lorikeet is not adapted to live and breed in the New Zealand environment, poses no threat to native birds by competition for food or nest sites, and poses no threat to the horticultural industry. The capture program of the rainbow lorikeet was said to be an unnecessary waste of taxpayer's money and departmental resources. Capture of the lorikeets is continuing in Auckland and, as a result of the publicity generated, a possible second population has been located more than 200km away. This example illustrates the controversy that can arise over control of an attractive introduced species, and the potential for different interpretation of the facts about a species, depending on the motives of the promulgators of the information.
7. *Freshwater fish*. Attitudes to introduced freshwater fish in New Zealand vary according to the species concerned, revealing some interesting inconsistencies. Among the species introduced and established by Acclimatisation Societies in the 19th century were brown trout (*Salmo trutta)*, rainbow trout *(S. gairdnerii),* perch *(Perca fluviatilis)* and tench *(Tinca tinca*). Of these, trout are the most widespread, and now form the basis of important recreational fisheries. Introduced trout are now widely recognized as being invasive predators in many parts of the world. In New Zealand, there is growing evidence of the negative effects of trout on native fishes and invertebrates, including declines and local extinctions of endemic galaxiid fish (McDowall, 1990). However, the negative effects of trout in New Zealand ecosystems have received little publicity and have caused virtually no official concern, largely because of the popularity of trout fishing and the strength of the "game" angling lobby. Other fish, including rudd (*Scardinius erythrophthalmus*) and koi carp (*Cyprinus carpio*) were illegally introduced

to New Zealand in the 1960s (McDowall, 1994). Along with perch and tench, they are fished for by a much smaller group of "coarse" anglers, most of whom are themselves recent immigrants from Britain. Rudd and carp can become the dominant fish species in waters where they thrive and, like trout, they have negative effects on native freshwater ecosystems, changing the structure and composition of the flora and fauna. However, unlike trout, rudd and carp are classed as "noxious" fish and are the subject of pest management strategies. Prominent among the concerns about these species are those of game anglers who fear that trout-fishing waters will be invaded by these less-valued "coarse" fish. The different official attitudes to species of fish that are valued by different groups in the angling community illustrates that official responses to invasive species can sometimes reflect the influence of special-interest groups, rather than objective assessments of risks to native biodiversity.

8. *Tussock moth.* The very distinctive caterpillar of the white-spotted tussock moth *(Orgyia thyellina*) was first collected by a member of the public from a peach tree in suburban eastern Auckland in April 1996. Native to Japan, Taiwan and Korea, this insect had established in this northern region of New Zealand following its accidental introduction one or two years before, and had the potential to cause severe damage to a wide range of trees and other plants. The distribution of this new pest was limited to an area of about 100ha of suburban Auckland. To kill it Foray 48B (containing *Bacillus thuringiensis* var. *kurstaki*), was applied using ground and aerial techniques, initially over 4000 ha of suburban housing, but this area was progressively reduced so that final applications were contained to only 300ha. The spraying programme commenced in October 1996 and extended into early March 1997. An intense media campaign about potential damage by this moth, and the safety of the toxin, accompanied this work. In all, 23 aerial and associated ground-spraying treatments were applied to the infected and buffer areas. Six males were trapped in April 1997, but no live stages of *O. thyellina* have been intercepted in the field since then (Hosking, 1998). This example illustrates the importance of surveillance for early detection of invasive species, the importance of involving the public, and the feasibility of obtaining widespread support for quite intrusive control, provided information is made freely available and those affected are fully involved.
9. *Ornamental plants.* Many plants introduced to New Zealand for ornamental purposes have subsequently proved to be invasive. Overall at least 240 species are now recognized as ecological weeds in New Zealand: invasive species that threaten native ecosystems (Williams, 1997). While New Zealand has a number of native clematis species, gardeners chose to import *Clematis vitalba* (native to Europe and south west Asia), also known as "old man's beard" and "travellers joy", for its greater abundance of flowers and showy seed pods. When this species was firmly established in the wild and seen to overtop and kill mature forest trees, many people became aware that introduced plants could become a threat to natural ecosystems. Climbing asparagus (*Asparagus scandens*), brought from South Africa as a decorative indoor plant, also went almost unrecognized in native ecosystems until it was seen to cover large areas of shrubland and understorey species within forest areas.
10. *Commercial plants.* Grasses, food, forage, shelter and erosion control plants have been introduced to New Zealand since human occupation began. Many of these have been subsequently found to be detrimental to the industry that imported them, to other commercial users or to natural ecosystems. Gorse (*Ulex europaeus*) was brought in from Great Britain as a hedge plant. It soon invaded pastures and was one of the earliest plants to be declared a weed. It also invaded abandoned pastures and burnt-over shrublands, but was found to be a relatively good nursery plant for native shrub and tree species in the latter habitats, if fire is prevented. Kikuyu grass (*Pennisetum clandestinum*) was brought in from Kenya, as it was considered to be a grass which continued to grow and produce

fodder in the dry summer months. It did this but some farmers consider that it reduces their overall production and now work diligently to remove it from their properties (M. Waller, pers. comm). When kikuyu invades regenerating shrublands it severely inhibits natural regeneration by overtopping young native shrubs and trees. Pampas grass (*Cortaderia* spp.) was brought in from South America for cattle fodder. It has now become a significant invader of natural ecosystems, particularly where small native plants would normally grow such as on cliffs and estuarine edges (Owen, 1997). The visible impacts of these and other plant invaders have alerted many people to the threats from invasive plants and have resulted in concerted action in many areas to manage plant pests.

Conclusions and recommendations

Human perceptions of invasive alien species in New Zealand, and the methods used to manage these species, have changed over time. As the human population of New Zealand becomes more urbanized and more informed, we can expect further changes in perceptions of the impacts of invasive alien species and the methods used to manage these species.

Knowledge about invasive alien species comes from the direct experience of the impacts of these species and from publicity related to those impacts. With increasing urbanization, the direct experience of impacts will decline and the importance of learning from a broadening array of information sources will increase. The strong biosecurity laws in New Zealand, economic dependence on primary production, and need to protect human health currently result in high levels of publicity and general acceptance of management of alien species affecting the agricultural and health sectors. The protection of natural ecosystems from invasive alien species gains less attention from the media and requires more deliberate and planned information dissemination. This planned publicity becomes more important when the invasive alien species to be managed is large, popular and/or attractive, and when as the native ecosystems or species to be protected are obscure, small or largely unappreciated.

Public opinion must never be under-rated. It is vitally important that sound information is widely available and all key interest groups are consulted and (where possible) involved in management decisions. Without public and political support, the effective management of the threats from invasive species is likely to be impossible.

Economic Issues

Socio-economic parameters influencing plant invasions in Europe and North Africa

Montserrat Vilà and Jordi Pujadas

Abstract

Human activities are the primary cause of intentional or unintentional introduction and invasion of species. However, the relationship between the socio-economic status of a country and its pool of invasive species has not been explored. We investigated the correlation between several socio-economic parameters and the density of naturalised plant species in European and North African countries. We found that density of alien plants is positively correlated with the extent of terrestrial transport networks, migration rates and importations and the number of tourists visiting the country. Development, estimated as the Human Development Index (HDI) and Gross Domestic Product (GDP), was also positively correlated with the density of alien species. Our analysis shows that development and movement of humans and commodities are major drivers of plant biological invasions.

Introduction

The homogenisation of floras and faunas around the globe due to species introductions and invasions is a consequence of human activities (Elton, 1958). The movement of humans and goods increase the opportunity for alien species to reach a new region, become naturalised and probably invasive (Hodkinson and Thompson, 1997; Lonsdale and Lane, 1994). For example, in some regions, the percentage of alien plants is correlated with the number of visitors to protected areas (Chaloupka and Domm, 1986). Transport networks (e.g. highways, railways, etc.) enhance the spread of alien species (Ernst, 1998). Likewise, the presumption that trading increases the introduction of aliens is also largely accepted among ecologists and land managers (Jenkins, 1996, 1999; Baskin, 1998). Overall, there is a general perception that development and progress increase the number of alien species (Jenkins, 1996). However, the quantification of such associations has scarcely been explored. Only recently, Baiocchi and Dalmazzone (2000) have analysed the relative importance of several economic variables on the share of aliens. They have found that disturbances associated to human activities and Gross Domestic Product per capita (GDP) are important determinants of the vulnerability of a given country to invasions.

In this paper we conduct a correlation analysis between several socio-economic parameters and the density of naturalised plant species in European and North African countries in order to explore the predictive power of parameters that integrate human activities on the abundance of alien plants. We chose this region because it constitutes a part of the Old World where the abundance and distribution of naturalised species has been fairly well documented (di Castri, 1989). Furthermore, this analysis allows us to explore the association between socio-economy

and naturalised plant abundance for Mediterranean basin countries, a region with very marked north-south socio-economic differences (Groves and di Castri, 1991; Le Floc'h, 1991).

Methodology

We used the density of naturalised plant species (i.e., ratio of number of naturalised species to $\log^{10}$ area) and not the number of naturalised species to avoid confounding effects with area (Lonsdale, 1999). Data of the density of naturalised species in European and North African countries were obtained from Weber (1997) and Vilà *et al.* (1999), respectively.

Socio-economic variables were extracted from the Central Intelligence Agency (CIA), World Development Reports, Yearbook of Tourism and the United Nations Programme for Development. The socio-economic variables tested were: population density, length of the terrestrial transport networks (roads, motorways and railways), net immigration rate, importation, number of tourists per year, GDP (Gross Domestic Product) and HDI (Human Development Index). The full data set included 28 countries. However, for some countries in the Balkan region it was impossible to get information on some of the variables. We conducted a correlation analysis with density of naturalised plant species per country as the dependent variable and each of the socio-economic variables as the independent variable.

Results and discussion

The most obvious relationship was the positive correlation between population density and density of naturalised plants ($r = 0.64$). An increase in population density of about 100 people/km^2 is similarly associated with an increase of 38 naturalised species/100km^2. The density of naturalised species was also positively correlated to the number of tourists that visit the country ($r = 0.49$). For example, Mediterranean Basin countries such as France, Italy and Spain that receive many tourists are the ones with the highest density of naturalised species. This may be directly related to the positive relationship between the number of visitors to natural areas and the number of alien species (Lonsdale, 1999) because propagules may be introduced on tourist vehicles (Lonsdale and Lane, 1994). Indirectly, accommodation services (i.e. hotels, holiday resorts) represent a major focus of alien plant propagules from garden throw-outs and topsoil movement (Hodkinson and Thompson, 1997).

Developing countries (i.e. North African countries and Albania) have a very low number of naturalised plants. This trend was also related to low HDI and GDP compared to developed European Mediterranean Basin countries ($r = 0.60$ and $r = 0.56$, respectively). Although the causes of these low values can be confounded with differences in flora exploration and biogeography (e.g. high proportion of arid land in North African countries), these patterns can also be explained by low immigration and importation rates compared to developed European countries ($r = 0.46$, $r = 0.69$, respectively). However, these patterns may change with time because increased standards of living in developing countries will be associated with increased demand for imported products, thereby increasing the likelihood of unintentional introductions through the import process (Jenkins, 1996).

Countries with more extensive terrestrial transport networks have a higher density of naturalised plants than countries with less developed terrestrial transport networks ($r = 0.62$). Prior to the present study, some of these relationships had been found for smaller areas such as regions within countries or natural reserves. For example, areas adjacent to roads and railways are rich in alien species (Pysek, 1994; Tyser and Worley, 1992), which spread fast in these habitats (Ernst, 1998). This relation is related to the naturalisation of alien plants used to restore railways, roadsides and highways, and to the turbulence created by passing cars and trains which enhances plant dispersal.

Management and research recommendations

Biological invasions are a global problem with solutions that may lie beyond the area of distribution of a particular alien species, and which concern should be extended to socio-economic sectors besides environmental and natural resource management agencies. Policy and management practices should be reinforced to deter propagule pressure of alien plants in European and North African countries. Recommendations should include:

1. Fostering cooperation between several economic sectors whose activities have the greatest probability to introduce alien species: industry, tourism, trade, agencies responsible for water supply, etc.;
2. Avoiding the use of alien plants in restoration and mitigation programmes and promoting the use of native species;
3. Improving the screening protocols to detect alien species in the borders between countries and at customs, especially when primary products are imported (e.g. wood, grains).
4. Increase the public awareness of plant invasions especially in protected areas highly visited by tourists.

We advocate that if ecologists are going to advise policies and management practices to deal with biological invasions, more research should be conducted beyond the ecology of biological invasions. We envision several avenues for future research at several spatial and temporal scales:

1. Including or concentrating on other types of organisms (i.e., animals, pathogens);
2. Discerning which components of development are more likely to influence introduction and spread of alien species;
3. Focusing on specific countries or regions (e.g., islands, coastal areas) and extend to the relationship between biological invasions and land-use variables (e.g., fragmentation, protected areas, existence of corridors); and
4. Relating flows (rates of change in the abundance of aliens) rather than pools (abundance of aliens at a specific point in time) to economic changes (Baiocchi and Dalmazzone, 2000).

This research agenda requires not only good data sets of naturalised species' abundance and distribution and how they have changed over time; it also offers an excellent arena for interdisciplinary research. Collaboration between ecologists, geographers, land use planners and economists is required to investigate in more depth the main (non-ecological) causes of biological invasions.

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Who should pay? Economic dimensions of preventing harmful invasions through international trade and travel

Peter T. Jenkins

Abstract

While the problem of biological invasions is becoming better recognized internationally, the funds available for dealing with the problem remain woefully inadequate. This paper suggests six policy tools to help ensure that those responsible for generating the problem pay appropriate fees to support appropriate management actions, including insurance requirements; bonding requirements; civil fines; criminal penalties and fines; fees; and corrective taxes. These need to address invasive alien species problems arising from intentional introductions, from travelling intercontinentally by ship or plane, or through importing cargo intercontinentally. Several national policy mechanisms are also available, including economic incentives and disincentives. The mechanisms proposed would be fair and appropriate, correlated with the amount of trade and travel, provide sustained funding for the long term, and be sensible to consumers, travellers, and policy makers.

Introduction

At the UN/Norway invasives species conference in Trondheim in 1996, a Kenyan delegate who agreed that trade could cause invasions, asked me a question for which I had no good answer: how could developing countries afford to pay for the necessary risk analysis, and for prevention, monitoring, and control systems? This paper looks at some economic aspects of that critical question.

A special double issue of IUCN's *World Conservation* (4/97 – 1/98) was devoted to the invasives problem. In the overview, Prof. Daniel Simberloff (1998) said that to slow the rush toward global biological homogenization, international policy makers needed to support three broad actions: (1) creating a less fragmented institutional response; (2) moving to a regulatory approach that allows no new non-native species to be imported unless they have been carefully assessed and shown to be safe; and (3) committing much greater funding to the multitude of demands in preventing the so-called accidental introductions and in controlling existing infestations. This paper discusses only Simberloff's action (3), the funding problem. But the funding problem needs resolution or else neither key international bodies nor the developing world likely will be able to implement actions (1) or (2).

The economic factors leading to invasives introductions may be as important as the letter of regulatory laws (McNeely, 1998). The U.S. magazine *BusinessWeek* recently published an excellent and frightening article on "Bioinvasions" (Ginsburg, 2000). It vividly described economic globalization's ecological "Dark Side" (to use Star Wars terminology). It focused on

several animal disease and microbial invasives threats, in both developed and developing countries, such as foot and mouth disease.

Ironically, later in the same issue is a lengthy Investor's Advice section entitled: "The New Global Investor: As frontiers vanish, opportunities are beckoning". It tells readers how to profit by investing in international ventures. Much of this investment, of course, will contribute to the trade and travel that is driving the bioinvasion phenomenon which the first article was about. This investment advice represents the inescapable human drive to wealth, which may not quite make the world go around, but it does make people and things (and their pests, weeds, and pathogens) go around the world. *BusinessWeek* – through subscriptions, advertising and special sections – and its readers are thriving from this drive to wealth.

People concerned about invasives and biodiversity are not necessarily trying to stop globalization, although they may slow some parts down and should keep up the good fight on the regulatory front to stop unfettered trade in risky articles, such as raw wood pallets and packing material. But we also need to find a way to thrive off of globalization's revenues, in the same way *BusinessWeek* does. We need to tap into global trade as a source for funds to fight the ongoing homogenization; to devise ways to get international businesses to recognize and take responsibility for their contributions to environmental problems (as in the case of the Montreal Protocol on Ozone Depleting Substances); and to increase consumers' awareness so they make better choices. This needs to be sold as a "smart trade" agenda, not anti-trade. And we need to recognize that smart trade can – not always will, but can – lift people globally to higher living standards and that is good and should be encouraged (IISD, 2000).

The bind here is that higher living standards could just make the bioinvasion phenomena worse. Increased standards of living are associated with increased international travel and increased demand for imported products of many kinds. This raises the likelihood of further harmful introductions. Imported products may include exotic foods, horticultural products, pets, aquarium plants, and so on that may become invasive later. The last ten years have seen a dramatic (more than 50%) increase in world trade accompanying the WTO, NAFTA, and other liberalization regimes. Government response funding has not kept pace. Future funding mechanisms, to be effective, will need to increase at least at the rate of the trade and travel, to be somehow tied to them in other words.

Holes in cost accounting

Recent accounting has suggested extremely high levels of damage caused by pests, weeds, and pathogens to forestry, agriculture, and other economic interests, and to human health. Pimentel *et al*. (1999) estimated that US$138 billion/year in damages are caused by harmful invasives in the United States, although this figure is based on very liberal interpretations. The U.S. Congress Office of Technology Assessment (1993) report estimates were much less, in the range of US$ 5 billion/year. Both figures relied on a weak literature base. Whatever the correct tangible loss figure, we should recognize that much of the damage lacks any tangible economic cost accounting. Instead the damage is in terms that are harder for the public and policy makers to grasp: reduced biodiversity; reduced ecosystem function; health effects; and aesthetic and recreational losses. The lesson here is that we should not tie preventative funding to monetary estimates of damage.

Where money needs to go

We need funding for alternative technologies that are less risky, and for transferring those technologies globally. Ballast water sterilizing treatment is a prime area for this. Another is to use only kiln-dried wood or non-wood cargo pallets and dunnage as an alternative to the extremely risky raw wood commonly used today. Raw wood packing materials from China are believed to have brought the dreaded Asian long-horned beetle into the northeastern United

States. Alternatives will be difficult to implement globally without significant funding. Ironically, the U.S. Congress debated and approved normalization of trade relations with China and support for Chinese entry to the WTO without mentioning the serious and ongoing invasives threats from that trade.

Capitalist tools

Several commenters on biological pollution have seen a need for better policy tools to internalize the externalities, that is, to shift to the "Polluter Pays" approach (Shine *et al.*, 2000; Bean, 1999; Glowka *et al.,* 1994; Jenkins, 1996; McNeely, 1998; OTA, 1993). This approach could both create a disincentive against causing biological invasions, and generate much more funding to prevent invasions or control them when they occur. Funding for developing countries to pay for even basic quarantine and risk assessment capacity is urgently needed (Schei, 1996).

One cannot enforce the Polluter Pays approach unless mechanisms exist to extract the Pay from the Polluter. How do policy makers ensure remediation funding in other fields in which mishaps or failures are foreseeable? Which policy tools serve to reduce the likelihood of a generally foreseeable category of mishaps or failures from occurring in the first place and to have funds to promptly respond if such events do occur? Some examples:

- In the world of automobile accidents, many countries have **mandatory insurance** laws.
- In the field of public construction, contractors often must post a **bond** to ensure funds will be available to pay the costs of completing and cleaning up the project if the contractor fails.
- Heavy **civil fines** can be imposed in the US, Canada, Japan, Europe, Singapore and elsewhere if an employer maintains a hazardous workplace.
- **Criminal penalties** (including criminal fines) exist for gross negligence or recklessness that leads to a preventable accident.
- **Fees** are extracted from users to cover particular foreseeable mishaps, e.g., mountain climbers in certain U.S. National Parks pay an extra fee when they obtain a climbing permit to fund search and rescue programmes.
- Specific **corrective taxes** are sometimes imposed. The 1987 Montreal Protocol on reducing pollution from chlorofluorocarbons (CFCs) and other ozone-depleting substances addressed environmentally harmful externalities of commerce, as are present in the invasives situation. In addition to the phaseout of these chemicals under the Protocol, the U.S. Congress imposed a heavy tax on U.S. CFC manufacturers and importers during the phaseout period (Arnold, 1995).

Thus at least six policy tools are available to internalize externalities, ensure accountability, and generate revenue: 1. insurance requirements; 2. bonding requirements; 3. civil fines; 4. criminal penalties and fines; 5. fees; and 6. corrective taxes. Their use to achieve invasives prevention goals has only been minimally analyzed in the past.

The first four of these tools have a "time lag" problem. Harmful invasive introductions can take years or even decades to manifest themselves, by which time the responsible party may be indeterminable. Even without this time lag problem, the precise cause of an introduction (perhaps just two opposite-sex non-native beetles flying off a ship in a port at night), is often impossible to determine accurately. Relying on insurance, bonds, civil liability, and criminal systems to assess individual accountability and recoup damages has not proven effective in the past (OTA, 1993). This is not to say they should not be used in clear cases, such as for animals imported to be held in captivity, but that the case too often is not clear.

The invasives cost internalization system needs to move from being reactive and ineffective to proactive and measurably effective. **The key to doing this is to apply the economic**

instruments at the very time the potentially damaging activity occurs and at the industry sector level. That leaves only two really helpful economic tools: fees and taxes.

Economists have argued for decades that the best way to achieve environmental goals is through appropriate fees and taxes to internalize externalized costs to the polluter, rather than just command and control regulations (e.g., Arnold, 1995; Dower and Repetto, 1994). But reasonable criteria are needed to categorize who is contributing to the problem and who makes sense to pay such fees and taxes.

Pathways as sources of fees and taxes

There is money out there. The value of world trade in goods in 1998 was US$5.2 trillion (WTO, 1999). The value of international airline passenger ticket revenues appears to well exceed US$100 billion annually (ICAO, 1999). I submit that the intercontinental transportation, export/import, and travel businesses, and the consumers/travellers who provide the demand, are the fair choice to be the funding sources.

I focus on intercontinental trade and travel rather than just international because this gets to the key pathways for harmful invasions, that is, between the seven continents. Intra-continent invasions and even intra-national invasions certainly have occurred, but not with the magnitude of impacts as intercontinental invasions. Also, applying economic policy tools to invasions at the intercontinental trade and travel level is simpler and easier to measure than applying those tools every time one of the 250+ national borders is crossed; and free-trade zones such as the European Economic Community would inhibit the application of these tools.

We should not get bogged down in arguing whether it is fair to seek contributions from those responsible for pathways that lead to so-called unintentional introductions. Analysts in the past oversimplified this issue by treating each introduction pathway as either "intentional", such as a sport fish release, or "unintentional", such as the discharge of a foreign marine organism in a ship's imported ballast water. The distinction is useful to a point, but it does not fix blame clearly enough on the shippers and import/exporters who cause so-called unintentional introductions. At some threshold of knowledge about a phenomenon, such as harmful ballast water discharges from the hundreds of ships that arrive in U.S. ports weekly, the people involved should be held responsible, even if we cannot say specifically who caused which invasion. What once were considered unintended consequences must be considered as fully intended when they are repeated over and over.[1] When an industry is on notice yet continues with the risky activity, ignorance of the specific harm is no excuse. So-called unintended, but foreseeable, harmful introductions actually can be viewed as fully intended by the industry as externalized costs of international trade and travel.

Airline passengers have objected to the practice in some countries of spraying cabins for potentially invasive insects which might, for example, have stopped the mosquitoes which are suspected to have carried the West Nile Virus into the New York City area. Airlines and passengers object to such spraying, and they would protest 100% inspection of passenger luggage for biological contraband. Both actions would slow down air travel further and could harm airline profits. Instead, charging a fee to pay for needed work to monitor and quickly stop airline-mediated invasions, and for public education, is a logical alternative.

A fair approach that most people, including policy makers, will understand is to extract the funds from the three main economic categories of intercontinental introduction pathways, outlined below. It is likely better to label the charges fees rather than taxes, because tax seems more negative and aimed at general revenue raising. Appropriate international institutions can develop tables as to what exactly is covered and what is a fair fee value. Clearly, many details would need negotiation.

- **Category 1 – Intentional Introductions: If you receive an intercontinentally imported plant or animal that is alive itself, or a live seed intended for planting, you should pay a fee.** This would include what are mostly non-necessities: ornamental plants, pets, aquarium species, aquaculture species, and anything else that is not completely infertile. Food, including seeds not intended for planting, should not be subject to this fee as raising costs of a basic necessity is unfair. Assessing at the import rather than the export stage will reduce a potential burden on export-oriented developing economies. Keeping this limited to the "intercontinental" level rather than "international" will sensibly exclude the extensive intra-continental traffic that has relatively low invasion risk, e.g., between U.S. and Canada, France and Germany, Kenya and Tanzania, and so on.

The challenge for prevention is unintentional introductions, both those that are foreseeable and those that are not; this is where who pays the fee could get messy. But like Category 1, above, people themselves are alive and they cause both unintentional as well as intentional introductions.

- **Category 2 – People: If you travel intercontinentally by ship or plane, you should pay a fee.** Like category 1, category 2 also is generally a non-essential activity. People are readily countable as they travel as intercontinental airline and ship passengers and could be taxed as such. Relatively little intercontinental passenger rail or vehicle traffic occurs, and it would be difficult to count, so it should be ignored.

So far we have live plant, seeds, animals, and human travellers covered, but what about those other pathways that aren't bringing in countable living entities?

- **Category 3 – Ship and Plane Arrivals: If you own a cargo ship or cargo plane that makes an intercontinental arrival with cargo in it, you should pay a fee.** These are readily countable, and serve as the major remaining pathways for unintentional but foreseeable and unintentional and unforeseeable introductions, including ballast water, insects flying off airplanes, and cargo sent by mail, by package service, ordered on the Internet, and so on.

This is not to say every person or business in these three categories contributes to the problem; rather it is to be proactive in assigning prevention responsibility to these intercontinental sectors, these beneficiaries from globalization, rather than trying to assign culpability after the fact, which too often is impossible. A finer-grained approach to identifying responsible actors would be impractical and could break down into endless arguments. Note that some efforts to accomplish some of this fee-setting may be going on now in various international forums, such as the International Maritime Organization. These should of course be encouraged. A concern is that grants to achieve some of these ends, as has occurred in the Globallast programme, may be one-time patches that will not be available over the long-term.

Again, what I am suggesting here is fees to pay for needed international and developing world prevention and education programmes. I emphasize prevention because it is easier to sell than a programme to control long-existing infestations. But I would not make that a hard and fast division because control-oriented programmes like Working for Water (Noemdoe, this volume) also serve to prevent the spread of new invasions to new areas, and serve capacity building and education. Plainly, international negotiations would need to elaborate criteria for collecting, holding, disbursing, and use of such funds.

In the issue of *World Conservation* dedicated to invasives, McNeely (1998) stated: "The literature on economic instruments available to support action in the field of biodiversity is vast and growing, but little of it deals specifically with the economics of invasive species. Since decision-makers like to hear arguments couched in economic terms, it is high time economists applied themselves to the problem. Without further delay, we should: build an economic

component into all international programmes dealing with invasive species; seek to quantify the costs and benefits involved in each country, or as part of each programme to deal with one or more invasive species; and mobilize economic instruments including such incentives as agricultural subsidies, grants, taxes, and fines, to ensure better implementation of programmes dealing with invasive species."

Just as atmospheric releases of ozone-destroying chemicals have been slowly but steadily reduced in the last decade through a combination of international cooperation, command-and-control national legislation, and strong economic instruments, including corrective taxes on production of those chemicals (Arnold, 1995), so too can decision-makers use fees to aid reduction and control of releases of harmful invasives. It will take national and international commitments of the quality and urgency that led to the Montreal Protocol on Ozone-Depleting Substances, broadly recognized as one of the most successful of the international environmental agreements. I have proposed what appears to be the most efficient, fair, and practical way to make the Polluter Pay in the intercontinental invasives context.

National economic analyses

This paper so far has aimed at potentially globally applicable economic instruments. But national policy makers also need to conduct detailed economic analyses of certain questions. (See also McNeely, 1999, and the conclusions of Perrings, Williamson, and Dalmazzone, 2000 for similar questions.)

1. What existing regulatory, financial, and penal disincentives could be adjusted to deter the risky trade and transportation activities? What specific levels of disincentives will serve the deterrence aim, or is deterrence impractical? Disincentives to be addressed should include (note that the weaknesses of some of these tools was discussed above): mandatory insurance or bonds; civil liability and fines; criminal penalties and fines; fees; corrective taxes; and other disincentives.
2. What incentives could encourage behaviour to avoid harmful introductions, to use native species rather than non-natives in appropriate settings, to control invasions, and to avoid land uses and other actions that will lead to more invasions? Incentives to be addressed should include: direct grants, aid, or subsidies; tax credits, exemptions, or other taxation benefits; compensation for losses or expenses incurred; rewards or bounties; jobs programmes; and other incentives
3. What incentives are potentially "perverse", that is, outcomes of too-strict laws that can make matters worse by driving risky imports underground?

As part of national efforts to slow invasives problems, these answers should provide useful information. Few developed, and fewer developing, countries have attempted to look comprehensively at these economic drivers.

Conclusion

We need to mobilize funding to make more people in more places have as their livelihoods the job of preventing harmful invasions, and educating other people how to do so. National efforts alone have not sufficed in the past and ongoing globalization makes them appear even more inadequate. Developing countries need assistance for capacity building. Money needs to transfer from the beneficiaries of globalization to people who are prepared and equipped to fight the biological flotsam it leaves in its wake.

An international agreement or protocol to an existing agreement could facilitate this, but the precise legal mechanism is beyond the scope of this paper. It could, for example, encourage parties to adopt national legislation to charge the payments and appropriate the revenues to an

appropriate international fund. In the absence of such an agreement or protocol, such taxes or fees, if imposed unilaterally on trade, may be challengeable as unfair trade restraints.

Key principles that an international funding initiative for invasives should support include:

- Fairness and appropriateness to major intercontinental invasion pathways.
- Correlation with the amount of trade and travel and sustained funding for the long term.
- A simple approach that makes sense to consumers, travellers, and policy makers.
- Pays to support developing world prevention and response capacity building and for additional administrative costs incurred by international bodies resulting from the initiative, such as the WTO, CBD, IPPC, and IMO.
- Pays for global public education and information programmes according to the best social marketing principles in both developed and developing worlds.
- The details are agreed through open, voluntary international negotiations open to all.

Notes

1. According to Glowka and de Klemm (1999), erasing the distinction between "intended" and "unintended" introductions was supported in at least one case by the Convention on Biological Diversity's (CBD) Subsidiary Body on Scientific, Technical and Technological Advice (SBSTTA). SBSTTA (1995) recommended that the CBD Parties should treat the use of non-native species in confined mariculture as equivalent to the intentional release of that species into the wild, due to the foreseeably high risk of escape. Unintended but foreseeable is the equivalent of intended in that case. I propose that "unintentional but foreseeable" be formally recognized as a category in policies relating to responsibility and accountability for invasives. So the three categories should be: "intentional", "unintentional but foreseeable", and "unintentional and unforeseeable".

Human Dimensions of Resource Management

Invasive alien species prevention and control: the art and science of managing people

Jamie K. Reaser

> … what I choose to do shapes a little bit of the world, and the ripples sent out by the actions of us all change the whole world for better or for worse.
>
> Philip Stewart

Abstract

Environmental conservation is a human value. Where we as individuals place this value among the hierarchy of our other values dictates the decisions we make and whether we behave in ways that protect the environment or do it harm. Invasive alien species (IAS) are a by-product of our values, decisions, and behaviours and reflect our identity and spiritual connections. Thus, IAS prevention and control is the art and science of managing people. In this chapter, I present a framework for the systematic analysis of the IAS problem – the human causes and the human consequences. These models are primarily derived from the field of communication psychology known as Neuro-Linguistic Programming (NLP). Once we stop focusing on IAS as the problem and focus on people's beliefs and resultant behaviour instead, new solutions become evident. We can evaluate existing programmes aimed at minimising the spread of IAS and better understand why they are or are not working, and what to do to make them even more successful. Examples and recommendations are provided in the areas of policy making, education/outreach, communications, and valuation.

Introduction

Environmental conservation is a human value. Where we as individuals place this value among the hierarchy of our other values dictates the decisions we make and whether we behave in ways that protect the environment or do it harm. The level at which we value environmental conservation is ultimately determined by who we believe ourselves to be as individuals and how we perceive our relationship to the world beyond ourselves. Invasive alien species (IAS) are, thus, a by-product of our values, decisions, and behaviours. They are an animate reflection of our identity and spiritual connections.

As IAS change the world for better or worse, they also catalyze us to change as individuals and a society. The condition of the environment in which people live influences their identity. For example, people consider themselves "poor" or "rich" based on their perceptions of the

abundance or scarcity of food, water, shelter, and disease. When IAS limit access to resources, or are limited as resources, those people most directly affected are prone to perceive that some aspect of "themselves" is threatened and take action based on this perception.

This chapter is an exploration of the human dimensions of IAS, drawn from my personal journey through the fields of ecology and psychology, international policy making, and the arts. It might be regarded as under the umbrella of the emerging field of "human ecology." It is my intention to present a framework for the systematic analysis of the invasive species problem – the human causes and the human consequences. Ultimately, I hope that the reader emerges with new insights for minimizing this problem and a heightened sense of motivation to address it.

Mental maps and neuro-logical levels

In the 1930s, Count Alfred Korzybski (1980), founder of the field of General Semantics, established that "the map is not the territory." He recognized that people's perceptions of their experiences forge a mental map of "reality." People relate to this map of the world, often believing that their map is the only "reality" to be perceived. However, two people can be in the same place at the same time doing essentially the same thing and have very different perceptions of the experience. They build different mental maps and respond accordingly in the future.

Anthropologist Gregory Bateson (1972) applied cybernetic (systems) thinking to biology, evolution, and psychology and perceived hierarchies to the way we classify experience – our mental maps. Robert Dilts has delineated this hierarchy as the six "Neuro-Logical Levels" (Table 1; Dilts and Epstein, 1995; Dilts, 1990; O'Connor and Seymour, 1990).

Table 1 The Neuro-Logical Levels.

Neuro-Logical Level	Reference	Scope	Neurological Engagement
Spirit	For whom or for what	Transmission	Holographic, nervous system as a whole
Identity	Who	Mission, Purpose	Immune system and endocrine system, deep life-sustaining functions
Beliefs	Why	Permission, Motivation	Autonomic nervous system (heart rate, pupil dilation, etc.), unconscious responses
Capabilities	How	Direction	Cortical system (eye movements, posture, etc.), semiconscious actions
Behaviour	What	Action	Motor system (pyramidal and cerebellum), conscious actions
Environment	Where, when	Reaction	Peripheral nervous system, sensations and reflex reactions

These levels are typically ordered by height or depth, with spirituality being the highest and deepest level. Our subconscious understanding of these patterns is reflected in the language we use, when we refer to someone as "greatly inspired," or being "deep" or "shallow," for example.

Spirit The nature of the spiritual relationships we have (or do not have) with entities greater than ourselves determines every aspect of our lives, fundamentally who we are to ourselves and others. Our sense of spirituality drives us to make choices and take actions for reasons that are "beyond us" – *to* or *for someone* or *something else*.

Identity Our identity is *who* we perceive ourselves to be. It determines our overall purpose (mission) and shapes our beliefs. Identity is the consolidation of entire systems of belief with respect to one's self.

Beliefs The beliefs we have determine *why* we do what we do, or do not do. They are our motivation and permission (or lack thereof), based upon certain values and criteria that we establish to support our sense of identity and spirituality. Beliefs enable or inhibit, and give scope to our capabilities, including particular skills, strategies, plans, etc.

Capability Our capabilities define *how* we do what we do. They are the particular skills, strategies, plans, etc. which guide and give direction to our behaviours. Through our capabilities, we choose and change behaviours to meet a diversity of needs (determined at the higher levels).

Behaviour Behaviours are *what* we do, the specific actions or reactions we employ in relationship to our environment. Although all behaviours are motivated and directed in response to the maps we construct at the higher Neuro-Logical Levels, they can be perceived (by ourselves and others) to be without direction, misdirected, habitual, or "knee-jerk."

Environment The environment is the context *where* and *when* we do things, the conditions under which we behave a certain way. We select or modify our environment to support our sense of spirit, identity, and values. Our environments are composites of specific external stimuli and internal perception. The stimuli determine the opportunities or constraints we perceive (consciously or subconsciously) we need to react to. We detect stimuli through our sensory systems (sight, sound, touch, taste, smell) and evaluate our resultant perceptions on the basis of Sub-Modalities, the qualities of experience (texture, brightness, loudness, sweetness, etc.; Faulkner, 1999; O'Connor and Seymour, 1990)

In the context of IAS, consider an example of a gardener thinking about his/her hobby at these levels:

Environment This spot in my garden seems bare and needs more colour.

Behaviour I am going to go to the garden centre and purchase a new plant that will be interesting and attractive.

Capability I will be able to find a new plant that appeals to me and is hardy in this climatic zone. I can afford a new plant and have time to add it to the garden this afternoon.

Belief I am sure that the garden centre will have lots of choices and I'll know the perfect plant when I see it.

Identity I am a very experienced and successful gardener.

Spirit Gardening helps me stay connected to the Earth and gives me a sense of inner peace.

As we move higher or deeper through the Neuro-Logical Levels, the experience becomes more abstracted from the specifics of behaviour and sensory acuity. The experience also has a more widespread effect on our mental maps and behaviour. While change at any level in the hierarchy will have an impact on all of the other levels, the level at which the primary change is made strongly influences the degree and direction of the secondary changes made at the other levels. This is due, in part, to the fact that varying degrees of neurology are involved in the change process; the higher the Neuro-Logical Level, the more complete the neurological engagement and the more systemic the change (Dilts and Epstein, 1995; Dilts, 1990; O'Connor and Seymour, 1990).

If you change your sense of identity, then your beliefs, capabilities, and behaviours will adjust to support this change. You will choose or modify your environment accordingly. Anyone who has gone from being single to married (or vice-versa) can attest to this. Likewise,

someone who decides to become a gardener will make changes in their life to support their new sense of identity – value attractive and hardy plants, frequent garden centres, buy gardening tools, purchase new plants, add plants to their garden, and care for the plants. Someone who decides to stop being a gardener and become an artist will change his or her beliefs, capabilities, behaviours, and environment to reflect the new perception of what it is to be an "artist."

Throughout history, people of all cultures have recognized that the environment influences behaviour (choices of shelter, clothing, etc.; Schama, 1995; Lewin, 1988). Modern science is now confirming that our beliefs and behaviours are shaped by a diversity of factors, including genetics, neurochemistry, experiences (mental maps), and the environment (Gallager, 1993). For centuries, the Chinese have practised Feng Shui – the Taoist art and science of using the environment to attain personal well-being (Sharp, 1999; Collins, 1996) – recognizing that when the environment influences spiritual perceptions the implications can be profound. Architectural scholars such as Frank Lloyd Wright (Larkin and Pfeiffe,r 1993; Lind, 1992) and Christian Norberg-Schulz (2000, 1965) have explored and capitalized on the social, psychological, and cultural effects of the integration of environment, spirit, and identity.

From this perspective, the Neuro-Logical Levels transform into a circular array of influence, a pattern of systemic communication (Figure 1). Our conscious mind is limited in focus and cannot perceive the entire communication loop, only small segments of it (Table 1; O'Connor and Seymour, 1990).

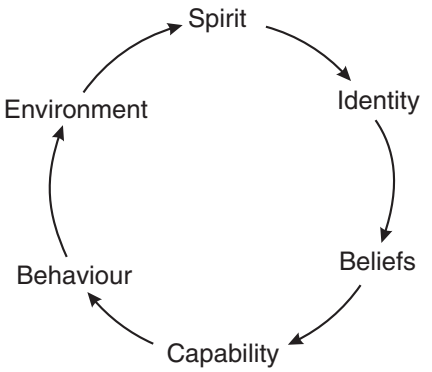

Fig. 1 Neuro-Logical Circle of Influence

Invasive alien species and beliefs

> It is in vain to dream of a wildness distant from ourselves. There is none such. It is the bog in our brains and bowels, the primitive vigour of Nature in us, that inspires that dream. I shall never find in the wilds of Labrador any greater wildness than in some recess of Concord, i.e. than I import into it.
>
> Henry David Thoreau

Invasive alien species are moved around because people engage in trade, tourism, transport, and travel. Sometimes the movements are intentional; someone is motivated by a desire to do something with the IAS (have it as a pet, for example). Sometimes the movements are unintentional; someone is motivated to relocate something else (themselves, equipment, non-invasive organisms – for food, fuel, shelter, etc.) and the IAS comes along for the ride (McNeely, 2000). Beliefs are our guiding principles. They form the basis of motivation and drive behaviour. Therefore, in order to understand why people move IAS, a prerequisite for stopping the movement, we must understand the structure of beliefs and how they can be changed.

Belief Structure

A belief is "confidence in the truth or existence of something not immediately susceptible to rigorous proof" (Webster's, 1991). Beliefs are largely unconscious patterned thinking processes, not necessarily based on a logical framework of ideas. In fact, they are notoriously unresponsive to logic. Beliefs are "maps" derived from experience. This may be direct experience, indirect experience, or interpretations of others' experiences (modelling). The most functional beliefs are usually those built from direct sensory experience (Dilts *et al*., 1990). However, all beliefs are delineated, and limited, by the mapmaker's tools – generalizations, deletions, and distortions (Chomsky, 1968, 1957). We apply and compare the beliefs we derive from one experience to another and our beliefs evolve as a result (O'Connor and Seymour, 1990).

Most of our beliefs are useful (enabling); they help us navigate through familiar and uncharted territory. Beliefs can also be limiting; they keep us stuck in place, unable to move forward and achieve what we want. Beliefs may be about cause, meaning, or identity. They may have to do with the environment (including other people), or they may be about your "self" (Dilts *et al*., 1990).

There are different constructions of belief, each with a different influence on the neurological system, and thus behaviour (Charvet, 1997; O'Connor and Seymour, 1990):

Presuppositions Presuppositions are simple assumptions, and probably the most common form of belief. Some presuppositions are expectations derived from direct experience, while others are interpretations derived from indirect experience or modelling. For example, "What I want can be bought." "Globalization benefits everyone."

Cause-effects These beliefs describe the relationship between actions and responses, or reactions. They are mapped in the form "X" causes "Y." "If I have an exotic pet, people will pay attention to me." "Increasing trade leads to economic growth."

Complex equivalence This form of belief ascribes meaning to our experiences. They are mapped in the form "X" equals "Y." Values and criteria are fundamental elements of complex equivalence. "The further I travel, the better the vacation." "The person who dies with the most toys wins."

Values Values are principles and qualities that determine the kinds of experiences we seek and those we avoid.

Criteria Criteria function as both the labels we give our values and the measuring devices (standards) we use to evaluate how well our values are supported in our experiences. Our criteria are used to determine what is good, bad, right, and wrong. Each person has his or her own definition for each criterion. Because criteria are so closely linked to values, and thus well ensconced in our neurology, the use of "criteria" words in conversation can incite strong physical and emotional reactions. Criteria are "hot buttons."

Meta Programmes

> The eye sees a great many things, but the average brain records very few of them.
>
> Thomas Alva Edison

In formulating and responding to beliefs, each person makes specific kinds of deletions, distortions, and generalizations (Cameron-Bandler, 1978). These "Meta Programmes" are the specific filters we use to map the outside world and select the behaviours that best express our internal world. These filters only let certain things in and out. These filters can, however, change in response to differences in the surrounding environment (context), as well as modifications to our perceptions at the other Neuro-Logical Levels (Charvet, 1997).

The class of Meta Programmes know as "Motivation Traits," provides a useful framework for understanding the filters that people apply when they decide to do something that results in the movement of IAS, or something to stop such movements (Table 2; Charvet, 1997). Offering information to someone using the language patterns that most motivate them will trigger their interest and action. Conversely, offering information to someone in the absence of these words or those of an alternate pattern will keep them from becoming interested and may "demotivate" those already interested.

Meta Programme patterns are described without value judgement. No pattern is "better" or "right." However, they can be more or less useful, depending on the context and the desired outcome.

Table 2 Meta Programme Motivation Traits (adapted from Charvet, 1997).

Questions to elicit pattern	Categories	Patterns
(no question at this level)	Level	*Proactive* – action, do it *Reactive* – try, think, wait
What do you want that IAS for?	Criteria	(see Hierarchy of Criteria later in chapter)
Why is that (criterion) important?	Direction	*Toward* – attain, gain, get *Away From* – avoid, exclude,
How do you know you have achieve what you want from having that IAS?	Source	*Internal* – knows within self *External* – told by others, facts and figures
Why did you choose that IAS?	Reason	*Options* – criteria, choice, possibilities, variety *Procedures* – story, how, necessity, didn't choose

We do not walk on our legs, but on our Will.

Sufi proverb

Consider these traits in the context of how we communicate what needs to be done about the IAS problem, and how we approach efforts to minimise the spread of IAS. [The percentages listed at the bottom of each pattern represent statistical distributions Roger Bailey found in the context of the work environment (as reported by Charvet, 1997)]:

Level This Meta Programme defines action. *Proactive* people initiate actions, quickly getting on with the task that needs to be accomplished. They are motivated by statements like "We need to solve the IAS problem now." *Reactive* people wait for others to take the lead, and/or methodically wade through a decision process (which may take a long time and never result in action). They are motivated by statements like "Think about what we would need to do to solve the IAS problem."

Proactive (15-20%); Equally Proactive and Reactive (60-65%): Reactive (15-20%)

Direction This pattern defines motivation and how people maintain (or lose) their focus. *Toward* people are driven by goals that they want to achieve. These people need to recognise their achievements and the steps along the way. They are motivated by statements like "When we eradicate cats from this island, it will be considered an a significant achievement and a step to accomplishing even greater regional goals." *Away from* people know what they do not want. They look for problems and take action to avoid them. They are motivated by statements like

"This IAS could cause severe impacts to our citrus industry and economic hardship for our growers. We must keep it from entering the country."

Toward (40%); Equally Toward and Away From (20%); Away From (40%)

Source This pattern defines where people seek their criteria (e.g., measures of success or failure etc.). *Internal* people use their own standards to compare information and make decisions. They "just know" what the answer is and have a tendency to resist a decision (even a good one) that is made by someone else. They are motivated by statements like "I'm sure you know that it is in your industry's best interest not to deliberately import and create a market for a plant that has proven to be an IAS in several other countries." *External* people rely extensively on other people to provide criteria and make decisions. They need others to tell them whether they are being successful or not. They are motivated by statements like "I think you should consider rangeland conservation your highest priority and therefore you should establish a program to remove leafy spurge."

Internal (40%); Equally Internal and External (20%); External (40%)

Reason This pattern defines how people decide what to do. *Options* people prefer to have choices and will seek out alternatives to directives (even if the directive is to use a tried and true procedure). They are motivated by statements like "There are a number of ways to approach this problem. Let's examine these three management options and select the one that will be the most effective for this situation." People with an affinity for *procedures* prefer to follow specific guidelines (but may not be good at developing them), especially if it is the "right" way to do something. These people are motivated by statements like "The best way to solve this problem is to educate pet owners not to release unwanted pets. Here's what will work: First we will find industry representatives that support our perspective, then we will work with them to develop flyers about the issue, and finally we will jointly put in place a campaign to give the flyers to each person when he or she purchases a pet."

Options (40%); Equally Options and Procedures (20%); Procedures (40%)

Further discussion of these patterns in the context of communication can be found under "Response Measures" toward the end of the chapter.

Hierarchy of Criteria

People map criteria in a hierarchical pattern. Some are more important than others and thus "demand" higher priority in decision making and actions. If you can identity the ordered criteria someone applies in a specific context, you can understand what motivates their behaviour, and to what degree (Charvet, 1997). We are more likely to be conscious of the lower criteria than the higher ones. The highest criteria most fully support our sense of identity and spirit, and are strongly motivating. "If I do this, I will have *security*." "This is a *God given* right."

Numerous authors have categorized the reasons that people have intentionally introduced IAS (Table 3). Low (this volume) points out that modern values (criteria), including love of mobility, freedom, speed, diversity, progress, familiarity, and a mechanistic view of nature, further contribute to our IAS problems. Hattingh (this volume) supports this perspective and points out a wide range of values (criteria) relevant to the IAS issue, including ecosystem health, biodiversity, naturalness, animal welfare, recreation, aesthetics, and economics.

Table 3 Reasons why people intentionally introduce invasive alien species.

Reasons (values/criteria)	Selected References
Recreate familiar conditions of home	Mack, 1999; Tenner, 1996; Osborne, 1994; Lever, 1992; Wright, 1991; Crosby, 1986
Increase financial resources	Binggeli, this volume; Hattingh, this volume; McNeely, 2000; Stickney, 1996; McNeely, 1996
Ensure familiar food resources	Mack, 1999
Ensure basic needs met – food, fuel, shelter, etc.	Binggeli, this volume; Mack, 1999; Hoyt, 1992
Provide medicine	Binggeli, this volume; Parker, this volume; Reichard, this volume
Ensure self sufficiency	Mack, 1999
Increase diversity	Hattingh, this volume; McNeely' 2000
Increase productivity (agriculture, forestry, fisheries)	Binggeli, this volume; Parker, this volume; Stickney, 1996; Williamson, 1996; Osborne, 1994; Hoyt, 1992
Adapt to changing conditions	McNeely, 2000
Increase aesthetics	Hattingh, this volume; Reichard, this volume; Tenner, 1996; Lever, 1992; Crosby, 1986
Increase environmental health (including biological control)	Bingelli, this volume; Hattingh, this volume; Marambe and Pushpa Kumara, this volume; Reichard, this volume; Bright, 1996; Williams, 1994; McNight, 1993; Waage, 1991
Ensure animal welfare	Hattingh, this volume
Create/augment "naturalness"	Hattingh, this volume; Stickney, 1996; Tenner, 1996; Lever, 1992
Create/augment recreational opportunities	Hattingh, this volume; Reichard, this volume; Bright, 1996; Stickney, 1996
Pursue scientific/intellectual interest	Binggeli, this volume; Marambe *et al*., this volume; Reichard, this volume; Bright, 1998; Tenner, 1996; Lever, 1992
Enhance warfare defenses	Binggeli, this volume

Although the reasons why people import and use IAS may appear to be independent and of equal weight, they are likely to represent different levels of criteria – even different levels of criteria for the same person in the same context. The hierarchy of criteria are specific to individuals and individual contexts. At the highest levels, the criteria may seem far removed from the topic of IAS. The same behaviour (for example, introducing fish) can be motivated by very different hierarchies of criteria:

Example A

Interviewer "Why did you release those fish into that lake?"

Interviewee (bait and tackle store owner):"I wanted to ensure there would be more fish to catch and people would be more likely to come here to fish." (augment recreational opportunities)

Interviewer "What benefit do you get out of people fishing here?"

Interviewee "More people are likely to shop in my store and I'll make more money." (increase financial resources)

Interviewer "What difference does that money make?"

Interviewee "I'll have more profit and thus more money to support my family – put the kids through school." (support family)

Interviewer "What does it mean to you to support your family?"

Interviewee "It's my duty as a father." (duty with respect to others)

Interviewer "What would happen if you failed in your duty as a father – to financially support your family in this way?"

Interviewee "Their security would be gone. My family might stop trusting me and not love me as much." (security, trust, love)

Example B

Interviewer "Why did you release those fish into that pond?"

Interviewee (college student) "I was going home for the summer and didn't want to take them with me." (free self of responsibility)

Interviewer "Why did you not just take them back to the pet store or give them to a friend?"

Interviewee "That would have taken more effort – to find someone else to take them." (convenience)

Interviewer "Why didn't you just flush them down the toilet like other people do?"

Interviewee "That's cruel. I want them to be free." (animal welfare)

Interviewer "What benefit do you get from them being free?"

Interviewee "They become part of nature, with the other fish in the pond." (augment nature)

Interviewer "What's important to you about them becoming part of nature?"

Interviewee "This is the place where I come when I am stressed out over exams and papers and stuff. It is peaceful." (peace)

Interviewer "What benefit do you get from this peace?"

Interviewee "I remember that I am connected to something greater than myself and my stress seems less...more manageable. I remember what I'm doing this for." (connection and service to something greater than self)

The reasons people either oppose or support actions to control IAS are sometimes related to the intended uses of the organisms, but not always. Frequently, the strongest opposition and

support reflect "higher order" criteria. This is why animal rights advocates, for example, are often perceived to be "highly motivated."

Consider the diversity and level of criteria reflected in the following statements, extracted from public comments received by the National Invasive Species Council (NISC) with regard to drafts of the U.S.'s Invasive Species Management Plan (version 2000-2002). Note that a criterion may be relevant to both sides of the debate. In fact, it is not unusual for proponents and opponents of an issue to hold the same criteria (although their definitions of the criteria may be quite different).

In opposition:

"This plan seriously limits our nation's overall productivity on many, many fronts. It often reads like a plot conceived by some foreign enemy to greatly weaken our country as a whole." [maintain national productivity and strength]

"This plan is more big government/big brother/red tape and bureaucracy for business people to have to hire lawyers and brokers to deal with." [minimize federal oversight and regulations]

"Other comments have suggested the complete elimination of imported plants and animals without study and examination of environmental and industry impact. This approach is akin in people to prejudice and even racism." [ensure well balanced scientific- and economic-based decision making]

"As this plan now reads, whether successful or not, it represents a "Pandora's Box" full of new weapons to be used against agriculture and the pet industry. Further empowering these extremist groups would be wholly unresponsible and similar to handing a loaded gun to a child involved in a playground dispute." [ensure security for industries trading in potentially invasive species]

"As someone who is interested in historic gardens and heirloom vegetables, I know that one person's treasure is another person's weed." [maintain hobby]

" … I think our govt. is too big already, and you'd be likely to target people who know nothing about plants, invasive or not." [minimize federal oversight and protect the "innocent"]

"This just confirms citizens' worst fears that all too often the United States is a government OF industry, BY industry, and FOR industry." [minimize influence of industry on federal decision making]

"Some of us have learned that anything that grows robustly or enthusiastically is not for our gardens, not if we want to grow anything else. That does not mean that I don't want to try new things from any country." [maintain ability to choose freely]

In support:

"I think we can all see the reasoning for being sure what the different kinds of plant/animal species are brought to any country they don't grow in naturally." [maintain naturalness]

"I don't know where Japanese beetles came from (how we got them) we can no longer grow roses – peaches – eggplant – basil – and the list goes on." [maintain ability to grow desired plants]

"At age 66, I don't know how long I can keep zapping garlic mustard, so I look forward to a safe biological control, which I hope will come from efforts by NISC." [reduce maintenance needs]

"In any case, thank you again for taking the time to write to a home gardener who worries about her planting choices being limited." [maintain ability to choose freely]

Hattingh (this volume) and Low (this volume) recognize that the values (criteria) people ascribe to IAS change over time. They also observe that many of the patterns of behaviour that we exhibit today may appear without direction, misdirected, or habitual because our behaviour doesn't necessarily keep pace with our changing intent.

The process of changing belief

> The problems that we have created cannot be solved at the level of thinking that created them.
>
> Albert Einstein

A belief, like a map, can be an invaluable tool in finding one's way around unfamiliar territory. Maps, however, like beliefs, can be outdated or simply wrong. Beliefs and maps must also be continually updated and compared to new experiences in order to ensure their evolution and accuracy. When beliefs and maps are not corrected, or there is an insistence to following an outdated version, someone will inevitably get lost (Dilts *et al*., 1990).

Beliefs can be a matter of choice – conscious decisions or the result of our unconscious selection of the filters (Meta Programmes) we use to processes experience. Beliefs that limit success can be replaced by beliefs that make it easier to achieve success. In order for this process to occur, a person must be open to doubting the current belief, be willing to let go of the old belief, identify a preferred belief, be open to having a new belief, and accept the new belief (Dilts, 1999).

Consider these examples in the context of IAS, continuing the previous interviews:

Example A.

Interviewer OK. I understand that you believe that introducing fish to that lake will enable you to increase your income (old belief). I find that interesting because just yesterday I was talking with another man who said he was removing the non-native trout in order to restore the native fish population. He said not only would more people come, but they were willing to pay more per catch for a true "wilderness" experience.

Interviewee I hadn't considered that. Hum. I must admit it kinda has a more romantic notion – fishing for something that is a part and parcel of this land rather than something that sloshed around in a farm pen for most of its life – probably from some other country too (open to doubt).

Interviewer So do you think you can equate making money with helping us recover the native fish in this area (preferred belief)?

Interviewee That's a possibility. I kinda have an idea that it might work (openness to new belief).

Interviewer So, if you can make more money and recover the native fish population at the same time, you'll be able to do good for your family and the wilderness. You'll be loved for that.

Interviewee Yes, that's true. We can do this. No more non-natives. I gotcha (new belief).

Example B.

Interviewer OK. So you were heading home for the summer and dumped the fish for your own good and theirs (old belief). I get it. But I'm curious about one thing...what good does it do you or the fish when a racoon eats them? There are racoons all over this campus.

Interviewee Geez, I hadn't thought about that! There are always racoon prints around the pond (openness to doubt).

Interviewer I think the only thing that would have for sure been good for the fish and given you peace of mind would have been to give them to someone else or take them back to the pet store (preferred belief).

Interviewee Sigh. Maybe the racoons won't get them. But, you could be right - and it wouldn't have taken much time to take them to the pet store (openness to new belief).

Interviewer So what is the right thing to do now? Knowing that the fish probably weren't safe and now you are worried about them?

Interviewee You are right. I can't get them back out of the pond, but I know other kids in the dorm were talking about doing the same thing. We should tell them all that the right thing to do is to take the fish to the pet store (new belief).

Changing beliefs enables behaviour to change. The more resources (capabilities, strategies, etc.) a person is given during the belief change process, the quicker the change in behaviour and the more long lasting. As Einstein recognized, limiting beliefs are most effectively changed at the Neuro-Logical Levels above which they were created. A belief change can also be accomplished by changing behaviour. This change, however, is not as reliable or likely as systemic (remember the direction of influence through the Neuro-Logical Levels). Furthermore, some people do not associate coincidences and are never convinced by repeated experiences (O'Connor and Seymour, 1990)

The field of Neuro-Linguistic Programming (NLP) offers many exquisite models of belief change and processes for changing beliefs, the details of which are beyond the scope of this chapter. The interested reader is referred to Dilts and Epstein, 1995; Dilts, 1990; O'Connor and Seymour, 1990; Bandler, 1985.

Response measures

IAS prevention and control is the art and science of managing people. Once we stop focusing on IAS as the problem and focus on people's beliefs and resultant behaviour instead, new solutions become evident. From this "human dimension" perspective we can also evaluate existing programmes aimed at minimizing the spread of IAS and better understand why they are or are not working, and what to do to make them even more successful. Consider these examples:

Policy Directives

Beliefs are our guiding principles. IUCN – The World Conservation Union (IUCN, 2000), National Invasive Species Council (2000), and Convention on Biological Diversity (CBD, 2000) have all developed guiding principles for the prevention and control of IAS (see websites listed under references). The guiding principles are largely directives for behaviour and capabilities (Table 4) – what should or should not be done by governments. For the most part, they fail to establish or support the enabling beliefs at the higher Neuro-Logical Levels. Thus, they fall short of their full potential to motivate and direct actions that will minimize the spread of IAS. Interestingly, they also neglect the "environment," the place where and when IAS are perceived to be a problem. (Note: In cases in which a guiding principle contained statements at more than one level, the primary statement was assessed, but not the supporting statements).

Table 4 Neuro-Logical Levels at which the major guiding principles on invasive alien species have been directed.

Neuro-Logical Level	IUCN Guidelines	CBD interim Guiding Principles	U.S.A. Guiding Principles
Spirit			
Identity			
Beliefs	4	2	10
Capabilities	7		5
Behaviour	18	13	5
Environment			

Education/Outreach

Staples (this volume) points out that environmental awareness is on the decline and that efforts to educate the public about IAS have so far been inadequate. In most cultures, the "education system" focuses on influencing people's capabilities and behaviour. The same focus dominates education/outreach messages and projects developed by the conservation community. To effectively minimize the spread of IAS, we must "aim higher" with our education/outreach programmes.

If people see themselves as gardeners (identity) with a flair for the exotic (belief-criteria), you are unlikely get them to stop planting potentially IAS by suggesting they now plant only native species (behaviour). If you can help gardeners see themselves as "someone who restores the environment" (for example), they will be able to adopt capabilities and behaviours that support the new definition of their identity.

Robert Dilts (pers. comm.) has identified categories of "change agents" with respect to the Neuro-Logical Levels (Table 5). Educators and coaches are needed to communicate what IAS are and how people can minimize the spread of IAS. However, knowing "how" and "what" are not enough. We want people to take actions to minimize the spread of IAS. People must be motivated to do what needs to be done in the way it needs to be done. Motivation is found at the level of beliefs and higher. "Education/outreach programmes" that engage the full spectrum of change agents will be the most effective.

Table 5 Type of agents needed to enable change at the various Neuro-Logical Levels. Adapted from Dilts (1990), Dilts and Epstein (1995), and Dilts (pers. comm.).

Neuro-logical Level	Reference	Scope	Type of Change Agent
Spirit	For Whom or For What	Transmission	Awakener
Identity	Who	Mission, Purpose	Sponsor
Beliefs	Why	Permission, Motivation	Mentor
Capabilities	How	Direction	Teacher, Educator
Behaviour	What	Action	Coach
Environment	Where, When	Reaction	Guide, Guardian

Communication

> You don't succeed for very long by kicking people around. You've got to know how to talk to them, plain and simple.
>
> Lee Iacocca

Browse through a news magazine or spend a few hours in front of the television. It will be readily apparent that the most persuasive communication stems from those who promote actions that ultimately harm the environment, not those wishing to protect it. The criteria (for example) being fed to us by marketing agents and the media are often likely to encourage, rather than minimize, the relocation of IAS. "Trade up." "Out with the old, and in the new." "It's all about paying less."

Good communicators shape their language (messages) to match their audience's map of the world. By matching people's criteria and Meta Programme patterns communicators can "preshape" information and ensure that the recipient can easily understand it. When people receive information that closely meets their needs, they are more likely to be highly motivated and promptly make decisions.

It's time for all of us who desire to minimise the spread of IAS to become good communicators. We need to identify the "maps" of the stakeholder audiences that are most important to us and align our communication campaigns with these maps. The same issue may need to be presented in vastly different ways. For example, consider a few of the criteria and Meta Programmes that make scientists and policy makers such distinct creatures (Table 6; Reaser, this volume; Reaser, 1999). Individuals in these fields tend to process information and respond to experiences differently, and it is these variations that often make communication between the scientific and policy making communities a substantial challenge.

Table 6 Difference in the criteria and Meta Programmes, and thus communication needs, of scientists and policy makers.

	Science	**Policy Making**
Perspective	"Macro lens"	"Wide angle lens"
Motivation	Towards understanding	Away from problems
Timelines	At least a couple of years	Crisis of the moment
Confidence Limits	Prove it	Acceptance of "fact"
Core Question	What is the truth?	What will work?

Scientists tend to be specialists. Their careers are made by knowing a lot about something specific. Many seek to know more about "something" than anyone else and dedicate their lives to this pursuit. Policy makers on the other hand are generalists. They must be able to converse generally about a broad, and ever changing, range of topics. Metaphorically, the perspective of a scientist is like that of a camera's macro lens and the policy maker like that of a wide angle lens.

Scientists are motivated to understand the structure and function of what they study. Their work is a step-wise progression toward identifying and understanding a problem. Policy makers are more likely to be motivated to move away from problems. It is their job to implement solutions quickly and keep their constituents out of less than desirable situations.

Scientists routinely complain that granting cycles are too short, that three or five years on one project isn't enough time to fully clarify the questions that they want to answer. In contrast, a

policy maker must respond to the crisis of the moment, often counting time to closure of an issue in hours and days.

Scientists typically believe that questions have provable answers and that, ultimately, it is this proof on which the direction and certainty of anyone's decisions should be based. Policy makers, however, tend to rely on others to deliver the "truth" and have a much higher likelihood of accepting information communicated by anyone labeled an "expert" as "fact". Ultimately, scientists are idealists, asking "what is the truth?" Policy makers are pragmatists, who seek workable solutions by considering numerous perspectives.

Situations do arise in which multiple target audiences need to be reached with a single communication and/or the "map" of the target audience is relatively unknown. In these situations, communicators can effectively "hedge their bets" by including a suite of the most likely criteria and as many Meta Programmes as possible. For example, someone might state "We need to minimise the relocation of IAS in order to move this country away from a situation that puts water and food security at risk, and concentrate on achieving our goals of health and well being for all people and the environment. I know you know this is true. The scientists and resource managers have evaluated many options and clearly there are ways in which we can do this right."

Valuation

Cost-benefit analyses predominate the government processes used to evaluate whether or not a specific IAS should be imported or controlled. The costs of known or potential damages from invasions (including costs of associated control efforts) are weighed against the net benefits derived from use of the organism (McNeely, 2000; Perrings *et al*., 2000; Naylor, 2000). Cost-benefit analyses are anthropocentric by definition and depend on an accurate evaluation of human values (criteria) (Goulder and Kennedy, 1997). Unfortunately, the process doesn't accurately reflect how people formulate and respond to criteria. In these analyses, criteria are assumed to have a standard definition and are typically weighted equally among people and for the same person. However, people define criteria differently and map criteria in a hierarchical pattern. As a result, individuals perceive some criteria as more important than others and feel that they should have higher priority in decision making and actions. If asked, people are likely to place greater economic value on their higher order criteria than their lower ones. The challenge is that most people are not consciously aware of their higher order criteria and these criteria may be far removed from readily quantifiable direct-use values. Nonetheless, it is important to recognize that an assessment that weighs a low criterion benefit against a high criterion cost (or visa versa) does not accurately reflect public perceptions. While someone may not consciously know what their high order criteria are upfront, they do know when their "hot buttons" have been pushed and will respond with vigorous opposition (as evidenced in the comments regarding the U.S. Invasive Species Management Plan). Clearly there is a need for further development of the tools we use for economic analyses. Efforts to minimize the spread of IAS are likely to be better supported if we can more effectively account for the "human dimensions of valuation" in our decision making processes.

Conclusions and recommendations

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

The following are recommendations for the application of the psychological models discussed in this chapter to efforts to minimize the spread of IAS.

1. Establish principles for policy guidance that explicitly promote the identities and values that motivate and direct people to minimize the spread of IAS.
2. In order to understand the structure and function of the relationships between people and IAS, identify the beliefs (enabling and limiting) and criteria associated with IAS (for specific target groups).
3. Use the findings derived from #2 to develop "education/outreach" and communication programmes that meet the information needs of the specific audiences and are highly motivating.
4. Expand IAS "education/outreach" programmes to engage the full spectrum of change agents.
5. Use the findings derived from #2 to undertake cost-benefit analyses that that recognize differences in definitions of criteria, account for the hierarchical spectrum of criteria, and weigh criteria of equal ranking.

Invasive alien species are a by-product of human values, decisions, and behaviours. They are an animate reflection our identity and spiritual connections. Thus, programmes to prevent and control IAS need to be built upon an understanding of the underlying causes of human behaviour, as well as processes to direct and motivate it. The field of psychology known as Neuro-Linguistic Programming (NLP) offers many models that can be incorporated into IAS programmes. Clearly, efforts to limit the spread of IAS need increased collaboration among experts from diverse disciplines – psychologists, economists, biologists, policy makers, communicators, and educators of all kinds.

It should be noted that the models presented here only "scratch the surface" of what the field of Neuro-Linguistic Programming (NLP) has to offer to the IAS issue. I hope that the insights this chapter has contributed will encourage the reader to investigate the field more thoroughly and incorporate relevant models and processes into his or her work.

> People are "signified" in our metalanguage as the problem … In any future metalanguage, people must be "the opportunity".
>
> P. Stott

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Dealing with the human dimensions of invasive alien species within New Zealand's biosecurity system

Paula Warren

Abstract

This paper provides an example of how a country, in this case New Zealand, can incorporate considerations of invasive alien species within a system of legislation, public policy, and resource management. A critical element is determining a transparent decision-making process that enables relevant interests to be represented, always within the framework of the public interest. Another important element is the balance between costs and benefits, informed by human dimensions such as intrinsic values and Maori cultural considerations. Decision makers need to assess the risks of any judgement that may be made, often in the face of considerable uncertainty. Dealing with IAS involves societal choices that can be informed by science. The ultimate decision, however, is a human one, based on careful consideration of all relevant factors in the public interest.

Introduction

As an island nation with a long independent evolutionary history, New Zealand is especially vulnerable to invasive alien species (IAS). In response the country has developed a biosecurity system with three core elements:

- Controls on the intentional introduction of new organisms into New Zealand, or the creation of genetically modified organisms within New Zealand;
- Controls on the movement of goods and organisms that might result in unintentional introduction of alien species;
- Eradication or control of invasive or potentially invasive alien species that are present in New Zealand.

Carrying out this work involves risk assessment, decision-making and on-the-ground management work. All of these are affected by and have an impact on the interests of people.

Societal choices

Decisions about alien species and risk goods involve making choices. The basis for those choices must be determined by society. Decisions are judgements. Science can inform but not make those judgements.

Who Should Make the Decisions?

The decision-maker should be the appropriate body given the nature of the decision. In deciding who is appropriate, account should be taken of several factors, based on an analysis of who are the relevant communities of interest. For example, a decision may affect primarily the local community, with little impact on anyone else. Alternatively, it could have major implications for the national community of interest. The decision-maker ideally should be accountable to the significant communities of interest, so in the case of an issue largely affecting the local community, it would be appropriate for the decision to be made by a locally elected body (in New Zealand this would be a local authority); if the national community of interest is the primary group, then a central government Minister may be most appropriate.

Decisions need not always be made directly by elected and directly accountable people. This is clearly desirable where the decision involves a significant political element. But if the decision is largely technical in nature, then an appointed and expert body (for example departmental officials or an appointed committee) would be more appropriate. Even where the decision is to be made by an elected body, it is often desirable to ensure that it is serviced by an expert group.

Relevant to this is whether the decision-maker is significantly constrained by legislation or other guidance, or has considerable discretion. Greater discretion implies the need for a greater focus on process and accountability. In New Zealand, decisions in fields with little guidance in law tend to be made by elected representatives.

It will also be necessary to decide how many layers of decision and appeal will be provided, and the nature of any appeals. In New Zealand legislation, several approaches are taken:

1. The primary decision-maker is the final authority, subject only to High Court review based on administrative law principles (i.e. reasonableness, fairness, proper considerations and process and the like). If the High Court rules that a decision was improperly made, the Court generally will direct the original decision-maker as responsible for making a new decision.
2. As for (1), but with an option before the decision is made to "call-in" the decision either from the non-elected decision-maker to a Minister, or from a local authority to a Minister.
3. The primary decision can be appealed to a body that considers it "de-novo" and makes the final decision. In this situation, the decision can then only be subject to appeal on points of law.
4. The primary decision is a recommendation to a Minister, subject to de-novo appeal, with the product of that appeal being a final recommendation to the Minister. The Minister's decision is subject to appeal on points of law. (Note that this is an unusual arrangement not without its critics.)

Appeal on points of law may be made to as many as three Courts (High Court, Court of Appeal, Privy Council).

In New Zealand, decisions on alien species issues are made at three levels:

1. The democratic process, through Parliament, sets the overall rules. These are expressed within legislation and regulations. The rules may be highly specific and rigid, or they may establish the matters that will be considered in decisions. Parliament also specifies who is responsible for lower level decisions.
2. Major decisions, particularly those with a political element, may be made by the appropriate elected Minister. The Minister must act within the constraints set out in the legislation, and is subject to High Court review. The Minister may, in some cases, delegate decisions to officials, but retains accountability for the quality of the decisions.

3. Day to day decisions may be assigned to non-elected officials or appointed committees. Again, the decisions must be in accordance with the legislation, and are subject to review by appeal authorities and/or the courts.

Involving the public in decision-making

Because decisions involve making choices on behalf of society, and because the results of those decisions affect societal and private interests, it often will be appropriate to allow public input to significant decisions.

The New Zealand courts have established principles for consultation processes, including being open to new ideas, encouraging participation, giving those being consulted adequate information to allow them to effectively participate, allowing enough time for the public to respond, and providing feedback on decisions. Processes for public input need to be carefully designed to:

- allow effective participation by the public;
- prevent inappropriate influence on the decision-maker;
- ensure that the decision-maker does not take into account irrelevant matters;
- ensure that the decision remains with the correct decision-maker and that the decision-maker remains accountable to the right people;
- allow the decision-maker to distinguish between real and perceived risks;
- increase public confidence in the decisions;
- ensure that costs (including delays) are not unnecessarily increased by the inclusion of the public process.

New Zealand approaches public involvement in several ways. First, legislation increasingly sets out very clearly and in considerable detail the process by which decisions are to be made, who is to make the decision, and what matters are relevant considerations for that decision. Any deviation from these statutory requirements would be likely to result in the High Court ruling the decision invalid.

Second, processes are in place to make decisions transparent. The basis for the decision should be clearly set out in writing (e.g., in a report by officials to the Minister or local authority hearing committee). All documents considered are (with minor exceptions) available to the public under the official information legislation. The nature and reasons for the decision must be clearly stated.

Finally, the legislation also makes clear who may have input into the decision (who has standing), and what process will be used for allowing that input. In addition, New Zealand has a strong community ethic opposing any forms of corruption, and the public actively use these mechanisms to scrutinise and challenge decisions. As a result, corruption in decision-making is almost completely absent.

Public input is provided in two main ways. First, legislation often requires the decision-maker to operate a specific public process, specifying the way the decision-maker must advertise the fact that the decision is to be made; which directly affected parties must be notified; that written submissions from affected parties are to be accepted; and that if any submitter wishes to be heard, a public hearing must be held. In addition, submitters may appeal the decision if they are dissatisfied with the way their submission was addressed.

Second, New Zealand has many quasi-autonomous non-governmental organisations (quangos), appointed by a Minister. The appointees may be selected from public nominations, or from nominations by particular interest groups specified in the relevant legislation. The body will have certain rights to inquire into matters of public interest, and to give advice to the Minister and/or other bodies. They provide an alternative method for the public to influence the

behaviour of decision-makers and resource managers. For example, the Minister of Conservation and her department are advised by a New Zealand Conservation Authority and 17 local Conservation Boards appointed by the Minister. They are expected to provide a voice for public opinion on conservation matters, including decisions on pest control work.

Public processes can be costly, and can slow decision-making. New Zealand legislation often allows minor or urgent decisions to be exempt from public process requirements in order to reduce unnecessary costs. For example, in the case of new organism importations, organisms which meet the requirements to be considered "low risk" organisms are approved through a process that does not involve public submissions and hearings.

Cost-benefit analysis

Choices are essentially the result of considering the balance between costs and benefits of an action. New Zealand's biosecurity system deals with costs and benefits in several ways. Certain costs associated with the arrival of new alien species are judged by Parliament to be unacceptable. Decisions cannot be made which would allow those costs to be accepted, no matter how high the benefits might be. For example, the Hazardous Substances and New Organisms Act 1996 states that certain organisms are prohibited from New Zealand. They cannot be imported, nor can they be trans-shipped through New Zealand. Currently 43 organisms, genera, families or classes of organisms (e.g. all snakes) are prohibited. Additional organisms can be added to the list by Order-in-Council (a process involving the executive body of the Government plus the Head of State).

The Act also sets minimum standards for imported species. If a species does not comply with the minimum standards (which cover risks to biodiversity and human health), it cannot be approved even when supported by evidence of high benefits from importation. For intentional new organism importations, if these minimum standards are met, a cost-benefit analysis is then undertaken. Essentially, the legislation allows the importation if the positive benefits outweigh the adverse effects.

The Biosecurity Act 1993 is based on the presumption that risks of unintentional introduction of alien species associated with the importation of goods or organisms must be controlled to an acceptable level. The cost of achieving that level of risk is considered, but this only operates at the margins. Essentially, the benefits of importation are not a relevant matter in deciding what level of risk will be accepted. But equally, without evidence of risk, the good may be imported even without evidence of benefits from the importation.

For control of already-established pests, a cost-benefit analysis is also undertaken. This will consider the benefits of the proposed control and the costs (direct and indirect) of undertaking that control.

What costs and benefits are relevant?

The legislation controlling the consideration of new organism importations clearly addresses this matter. It defines "effect" to include:

1. Any potential or probable effect;
2. Any positive or adverse effect;
3. Any temporary or permanent effect;
4. Any past, present, or future effects;
5. Any acute or chronic effect; and
6. Any cumulative effect which arises over time or in combination with other effects.

The type of effects which are relevant to at least some statutory decisions about alien species importations, risk goods and pest control, include effects on:

1. Indigenous and valued introduced flora and fauna;
2. The intrinsic value of ecosystems;
3. The environment;
4. Public health;
5. Cultural values of Maori;
6. Recreational values of the environment;
7. Economic matters; and
8. New Zealand's international obligations.

Many of these matters have a strong human dimension (or indeed may be purely about human values), including concepts of intrinsic values, valued species, Maori cultural considerations, economic effects, and international obligations. For example, New Zealand recently assessed whether eradication should be undertaken for a new incursion of painted apple moth. This work identified potential negative impacts on private amenity, public amenity, plantation forestry, horticulture, the protected area network, watershed conservation, human health and trade. These costs were assessed, and a dollar cost estimate of each was made to provide an overall economic cost. The overall economic cost was considered sufficient to justify the continuation of an eradication programme.

In the case of an incursion of varroa mite (which attacks bees), the situation was more complex. Varroa mite can devastate bee hives. Where the mite is present in a country, constant control through the use of pesticides is necessary. Until varroa arrived in New Zealand, no pesticide use was necessary in the New Zealand beekeeping industry, and this ability to operate without chemicals was highly valued by many beekeepers. New Zealand had one opportunity to eradicate the mite in order to avoid this.

Bees (in this case an introduced species) are essential pollinators for the horticultural and agricultural industry. Feral colonies are minor contributors, with most pollination being by domesticated bees. Failing to eradicate varroa mite would clearly have an impact on pollination, but eradication work (which would involve destroying thousands of hives and preventing hive movements) would also have a major impact in the short term. Eradication would have a major immediate impact on the beekeeping industry, but successful eradication would have provided long term cost-savings to that industry.

On balance it was decided that the likelihood of eradication being successful (because the mite had already reached feral hives in rugged country) was too low to justify the short term costs of attempting eradication, and that it was better to move directly to a control strategy.

This case study is also an excellent illustration of the impact of human perceptions. The mite almost certainly entered New Zealand by deliberate smuggling of infected bees by members of the beekeeping community. Their perception of risk was presumably faulty (it is unlikely that they deliberately attempted to sabotage their own industry).

Risk assessment

A key part of any judgement is to assess risks. Risk analysis is a management tool that incorporates scientific methods to enable the decision-maker to gather and assess information in a thorough, consistent, logical and transparent way. It allows predictions to be made based on current knowledge. The confidence we can have in such predictions depends on the amount and reliability of the data used. A key part of any sound judgement is to assess risks.

In addition to actual risks, however, the decision-maker may need to consider the issue of perceived risk. Public perceptions of risk will not necessarily match the assessed actual risk. The public are likely to over-estimate some risks and under-estimate others. Different people

will have different perceptions. Education processes will reduce the degree of inconsistency between the two risk assessments, but it is unlikely that education can completely remove it. Where the scientific assessment of risk has a high level of uncertainty, making a judgement based on that assessment which is contrary to the public perception would be likely to result in societal opposition. In these circumstances, the decision should probably be treated as a political decision.

Risks to certain values (e.g., cultural values, ethical values, intangible values) may be very difficult to assess in a scientific way, and the perceived risk may be the only valid assessment. These factors are difficult to incorporate into decision-making, since to rely totally on the assessment of risk by the affected party would be to assign accountability to that party. That would be inappropriate if that party is not the decision-maker under law.

Dealing with uncertainty

Uncertainty is a fact of life in assessing costs and benefits of alien species issues. It may arise from a lack of information or from a lack of agreement among experts on how available information should be interpreted. The need to apply a precautionary approach to these uncertainties is widely recognized in international and New Zealand law. Where the decision-maker's professional judgement is that they can't be satisfied on the information available that an importation will be safe, or that not eradicating a pest is acceptable, they would ordinarily deny approval for importation or eradicate the pest. It may be appropriate to make an initial decision and then seek further information to reduce the level of uncertainty, allowing an alternative decision to be considered at a later stage.

If a decision is made to accept a level of risk, but knowing that there is a significant uncertainty in the information on which that decision was based, the decision-maker should take steps to monitor the situation, seek further information, and if necessary reverse the decision if subsequent events show that the decision was wrong. The degree of uncertainty that is acceptable would depend on the severity of possible negative effects, and the likelihood of reversing those effects (e.g. the likelihood of eradicating a species if it proves to be invasive).

Sharing the costs

As well as assessing whether costs are acceptable, it is also necessary to determine who will carry those costs. This has several key elements. It may be possible to alter the nature of the costs and in so doing alter the affected party. The economics term "internalisation" is often used for this process. For example, import health standards that require certain treatment of a risk good before it leaves its port of origin (e.g., fumigation of a container) may impose a financial cost on the importer, but remove or reduce an environmental risk/cost for New Zealand society. In effect, the cost of importation has been transferred from New Zealand society and environment to the importer. The cost has been internalised.

Where an action has a direct financial cost (e.g., control of a pest species in New Zealand, or of a decision-making process), a number of parties could bear that cost. For example, a statutory process is in place for developing national or regional pest management strategies that identify those pests that the community should be collectively controlling. Once a strategy is approved, the management authority which prepared it has a wide range of powers to achieve its implementation, including requiring landowners to carry out pest control work at their expense. In effect, the strategy provides a mechanism for ensuring co-ordinated control action across all landowners/sectors, and allocating the costs of control efficiently between those exacerbating the problem and those benefiting from control. The way costs are allocated should provide the right incentives to minimise the problems.

New Zealand legislation also generally places many or all of the costs of decision-making on the applicant who will benefit from the decision (i.e., user pays approach). This may not always be appropriate, however. It is necessary to consider whether the costs of complying with a statutory process might act as a perverse incentive for illegal actions, or a barrier to economic development.

Where the control of a pest imposes costs on an innocent party, New Zealand's legislation sets out how compensation will be assessed and paid. For example, the Biosecurity Act 1993 provides that where goods are requisitioned or destroyed during pest control work, the owners will be compensated so that they are in no better or worse position than anyone who was not directly affected by the control work.

Conclusions

Dealing with invasive alien species involves societal choices. Science can inform but not make those choices. The decision-maker should be the appropriate body given the nature of the decision. In deciding who is appropriate, account should be taken of:

- What are the relevant communities of interest, and to what community of interest is the decision-maker accountable;
- Whether the decision involves a significant political element, or is largely technical in nature; and
- Whether the decision-maker is significantly constrained by legislation or other guidance, or has considerable discretion.

It is also necessary to decide how many layers of decision and appeal will be provided, and the nature of any appeals. Because decisions involve making choices on behalf of society, and because the results of those decisions affect societal and private interests, it will generally be appropriate to allow public input to significant decisions.

Choices are essentially the result of considering the balance between costs and benefits of an action. It is important to determine in advance what costs and what benefits are relevant to the decision, the relative weight that will be assigned to particular costs and particular benefits, who will bear any costs of the decision-making process, and of the final decision, and how uncertainty will be handled. Uncertainty is a fact of life in assessing costs and benefits of alien species issues, and a precautionary approach should be applied.

Human dimension aspects in invasive alien species issues: the case of the failure of the grey squirrel eradication project in Italy

Piero Genovesi and Sandro Bertolino

Abstract

The American grey squirrel, introduced to Italy and the British Isles as a pet species, replaces the native red squirrel through competitive exclusion. The potential expansion of the Italian population to the Alps and to a large portion of Eurasia represents a major threat to biodiversity at a continental scale. An eradication project of the Italian population, supported by most non-government organisations, failed because of the strong opposition by radical animal rights groups. In mainland eradications, time is constrained and delays caused by opposition can determine the failure of the entire campaign. Information may be irrelevant for reducing conflicts, because primary differences exist between animal rights and conservation groups. In these cases, a political decision needs to be taken. Awareness raising, revision of the legal framework, consultation processes, and the creation of biosecurity agencies, appear fundamental steps for effectively addressing the threats posed by invasive alien species.

Introduction

The red squirrel (*Sciurus vulgaris*) is considered threatened in Europe due to the fragmentation of its woodland habitats and the competition with the American grey squirrel (*Sciurus carolinensis*). This alien species, introduced into Great Britain and Italy, replaces the native red squirrel in all overlapping areas through competitive exclusion (Skelcher, 1997). The grey squirrel was introduced into Great Britain and Ireland several times from the end of the last century, causing the progressive disappearance of the native red squirrel from a wide portion of the two islands (Reynolds, 1985; Gurnell and Pepper, 1993), and severe damage to forests and commercial tree plantations (Rowe and Gill, 1985; Dagnall *et al*., 1998). Bark-stripping activity inflicts wounds that severely degrade timber quality and can facilitate the penetration of insects and fungi (Kenward, 1989). It is remarkable that grey squirrel produces little damage to trees in its native area in North America (Kenward, 1989).

Italian data confirm the competitive exclusion of the red squirrel from the grey squirrel range. A distribution survey in the area where grey squirrels are present showed a reduction of 46% in the range of the red squirrel from 1970 to 1990, and a further decrease of 55% from 1990 to 1996 (Wauters *et al*., 1997a). The mechanisms of the replacement of the red squirrel by the grey one are not yet clear and several hypotheses have been suggested (Skelcher, 1997). The most robust explanation seems linked to the higher efficiency of the grey squirrel in the exploitation of food resources, especially in broadleaf and mixed forests. An animal disease,

parapoxvirus, has also been implicated; the grey squirrel is suspected to be a source of this virus that is lethal to the red squirrel (Sainsbury *et al*., 1997).

Grey squirrel introduction and expansion in Italy

The grey squirrel was introduced in 1948 by an Italian diplomat who imported two pairs of animals from Washington DC for enriching the park of his villa, located in the south of Turin (Piedmont, north-western Italy). The squirrels rapidly established a population in the surrounding woodlands of Stupinigi. From their introduction until 1970, the grey squirrel was recorded only close to the release site, occupying an area of about 25km^2 (Wauters *et al*., 1997a). Subsequently, the species started to spread into the surrounding area: in 1990 the species' range reached 243km^2, increasing in 1997 to 380km^2. After 1997 the range showed a dramatic increase, and in 1999 the grey squirrel occupied an area of 880km^2 (Bertolino and Genovesi, in prep.).

In Italy, the grey squirrel has colonised a mean of 17.2km^2 per year, similar to the values reported for Great Britain (18km^2/year, Okubo *et al*., 1989). The colonisation of new areas has not been constant since 1970, ranging from 1.1km^2/year in the first phase, when their spread outside the wooded area of Stupinigi was hindered by the presence of extensive cultivated fields with a very reduced and fragmented woods, to 10-20km^2/year once the species started spreading along the rivers, and recently increased to 250km^2/year, when the grey squirrel reached the hilly areas of eastern Piedmont and the Po river (Bertolino and Genovesi, in prep.).

In the Stupinigi woodlands, where the species was firstly introduced, a survey estimated a density of 0.5 ind./ha (Wauters *et al*. 1997b). In Racconigi, in a 170ha park of which 70ha are covered by mixed deciduous old growth forest, a density of about 5 ind./ha was estimated in the same year through a mark-recapture study (Bertolino unpublished), resulting in a total population of about 350 grey squirrels. Combining data from Stupinigi and Racconigi, obtained an average squirrel density of 1.27 ind./ha and, considering the extent of the woodlands present in the current range of the species, a total population size of 2,500 animals was estimated (Wauters *et al*., 1997b). This estimate likely represents a minimum value, and in 1997 we assumed a population size ranging between 2,500 and 6,400 individuals (Bertolino and Genovesi, in prep.).

Awareness of the problem

The first records on the conservation risks related to the presence of the grey squirrel in Piedmont were published in the 1980s (Baratti, 1980; Cagnolaro, 1981; Currado *et al*., 1987). From 1989 several international organisations and scientists, including IUCN and the British Forestry Commission, informed the Italian authorities of the threat to the red squirrel posed by the grey squirrel, and urged an eradication of the species. In 1995 a first plan for the eradication of the grey squirrel was presented by the University of Turin to the local administration. The same year, the National Wildlife Institute (NWI, the Italian government agency for wildlife research and conservation) approved a recommendation to eradicate the grey squirrel from Italy, and alerted the Ministry of Environment, the Ministry of Agriculture, and all the local administrations (competent for pest management plans) in the grey squirrel's range, on the risks related to its presence. By 1996, the grey squirrel had greatly expanded its range, colonising areas only about 10km from the continuous hilly woodlands of the eastern Piedmont, suggesting that it could reach the Alps and the Apennines in about 2 years (Wauters *et al*., 1997a).

The eradication campaign

Realizing the urgency of removing the grey squirrel from Italy, in 1997 the NWI in co-operation with the University of Turin produced an action plan to eradicate the alien species. One of the first steps of the plan was the experimental removal of the small population present in the Racconigi park, in order to produce a pilot eradication scheme. It must be underlined that for the Italian legal framework, the local authorities (regions, provinces) are responsible for pest management actions, while the NWI is an advisory body that can provide technical support to the local authorities, but cannot directly carry out management plans. In this respect, the trial eradication was aimed to define technical methods, but further steps of the eradication would have to be carried out by the local authorities.

The project was sent to all main Italian NGOs for input and, on the basis of the comments received, the following protocol was adopted: 1) live-trapping of the squirrels, in order to avoid risks for non-target species; 2) frequent control of traps, to reduce detention of animals; 3) anaesthesia with alothane, a tranquilliser reducing stress in rodents; and 4) subsequent euthanasia of animals with an overdosage of alothane. On the basis of the revised protocol, most NGOs approved the eradication plan.

Opposition

Despite the fact that the procedure adopted minimised detention and used humane euthanasia of the squirrels, some animal right groups strongly opposed the project, asking for a radical revision and the use of alternative techniques not involving dispatch of animals. In a meeting between the co-ordinator of the project, researchers from the University of Turin, and the animal rights organisations, held in Turin in early April 1997, the various issues were discussed. Proposed alternatives – such as translocation of the squirrels to their original range (North America) or neutering of all squirrels and subsequent release – were discussed and rejected because they were considered unfeasible.

In April 1997 the project was officially presented at the Environmental Commission of the Regional Council, where representatives of most NGOs were also invited. On that occasion, the NWI underlined that the trial eradication in Racconigi was designed to provide information for the implementation of the subsequent eradication of the grey squirrel from the entire region, to be used by local authorities. A clear commitment by the local authorities was thus requested and obtained.

The meeting highlighted a fracture between the NGOs, with the conservation organisations (WWF, BirdLife, and others) supporting the project, and animal right organisations (League Against Hunting, League Against Vivisection) opposing it.

Trial eradication

Despite the conflicts, and in respect to the need to start the eradication not later than 1998 (predicted arrival of the grey squirrel to the Alps was 1999), the trial eradication started in May 1997, and the preliminary results were very encouraging. During only 8 days of trapping at Racconigi, 188 animals (>50% of the estimated population) were trapped and dispatched. Captured animals were introduced in a sealed box, treated with alothane, and monitored by a veterinarian to detect stress indicators and time needed for unconsciousness. The adopted procedure of euthanasia significantly reduced animals' stress; squirrels became unconscious in less than a minute, and could be euthanised in the field, with very limited manipulation.

Legal aspects

The animal right groups organised small demonstrations at a local level, then, in June 1997, they took the NWI to court, managing to halt the project. At the trial, the legal strategy used by the animal rights groups was based on the following charges: 1) a trial eradication cannot be considered research, and NWI cannot carry out a pest control programme; 2) euthanasia was not necessary, and the dispatch of the animals had to be considered as cruelty, 3) the removal of a protected species is damage to a State property. Point 3 was clarified by the Ministry of Environment, underlining the point that the removal of an alien species threatening a native one is an obligation of Italy. In December 1999 the court judged the two officers guilty of the first two accusations, with a penalty of 20 days in prison plus a fine. The judgement was appealed, and in July 2000 the Appeal Court of Turin found the two officers innocent of all charges. Nevertheless, the sentence affirmed that an eradication contradicts the principle of conservation affirmed by the Italian law (157/92), since conservation requires the protection of all species; the judgement thus represents a precedent potentially reducing the operational possibility to conduct eradications in Italy in the future. In this respect, an appeal to the Court of Cassation has been recently prepared.

Reactions

The case was reported by main newspapers, magazines and national television. Several messages were used by the animal right groups to oppose the eradication, both emotive ("slaughter of Cip and Ciop", the Italian name of the Walt Disney "Chip and Dale" cartoons), and technical (eradications are always impossible; it is not true that the grey squirrel replaces the red one; neutering and release of all animals should have been planned). Before the first judgement, most media reported the programme as a slaughter of innocent cute squirrels, through the use of a Nazi method: gas chambers. In most headlines, grey squirrels were called "Cip and Ciop". The animal rights groups were supported by Prof. Giorgio Celli, an entomologist at the University of Bologna and very popular in the country for the television program he hosts on a national TV channel. After detailed information was circulated to most media, several features reported our arguments (millions of red squirrels will die; eradication now means less grey squirrels killed in the future; Italy has the responsibility to halt the grey squirrel expansion). Technical attacks, and in particular the proposal of neutering and releasing all animals, were more difficult to counteract, also because of the support of Celli to these arguments.

A strategy adopted by animal rights groups was to declare that neutering all the animals was possible, but that wildlife managers do not like this option and prefer to kill them. Their position was enforced by the declaration that they were going to produce an alternative action plan, based on neutering. The action plan was never presented, but they obtained a further delay.

Although groups opposing the eradication raised technical objections on the need of the eradication, on the methods adopted, and on its feasibility, in several interviews they appeared to concentrate on animal welfare, and considered the extinction of a native species as a secondary problem. Statements such as "*Extinction of the red squirrel will occur in 20 or 50 years, so it is not my problem*" "*In such a time lapse, other and even worse ecological disasters may happen*" "*NWI should be closed, and an Institute for the protection of native and non-native species should be created*" were reported in several articles, making clear that the real conflict is between two different perspectives on primary values: conservation vs. animal welfare.

The national headquarters of the NGOs who had supported the project decided to adopt a low profile, because the defence of a project involving the suppression of cute furry animals, as the

squirrels indubitably are, was considered an unpopular position. Local NGOs supporting the project faced internal conflicts, with several membership cancellations.

The eradication was strongly supported by national and international scientific and conservation institutions. The Italian Mammalogy Society and the Italian Zoological Society produced statements underlying the need and urgency to eradicate the grey squirrel from Italy, and evaluated the project developed by NWI as scientifically and ethically correct. A resolution of the 4th European Workshop on Squirrel Ecology, held in Sweden in August 1997, recommended to the Italian authority the urgent removal of the grey squirrel, advocating the complete implementation of the action plan presented by the NWI. The Chair of IUCN's Species Survival Commission also supported the eradication plan through an official letter. The Council of Europe requested information from the Ministry of Environment on the reasons for the delay in eradicating the grey squirrel in respect to the obligations contained in the Bern Convention, and to the risk of expansion to other European countries. In December 1999, the Standing Committee for the Bern Convention approved its Recommendation 78 on the conservation of the red squirrel, urging Italy to remove obstacles to the eradication of the grey squirrel, and the Italian Ministry of Environment ensured the commitment of Italy to proceed in this direction.

Outcomes

Three years of legal struggle halted the eradication campaign. The early stop of the trial eradication prevented the implementation of the plan to remove the total population, and local administrations did not proceed with the planned eradication campaign. Since then, as a consequence of the suspension of the eradication campaign, the species has significantly expanded its range and the eradication is no longer considered feasible (Genovesi and Bertolino, 2000). In fact, the range of the grey squirrel has reached the continuous wood belt of the Alps and the hilly system of the eastern Piedmont, and has colonised residential areas where any operation would require the authorisation of private landowners. The Ministry of Environment asked the NWI to produce a strategy for the control of the grey squirrel, and after an assessment of the range expansion, the NWI proposed a strategy designed to: 1) identify and protect key areas for the conservation of viable populations of red squirrels; and 2) contain the grey squirrel in order to delay its expansion to neighbouring countries and to the mountain system of Italy (Genovesi and Bertolino, 2000).

Conclusions and recommendations

The opposition of the animal rights groups, although directly supported by only a small part of the public, was very effective in using the media, packaging its message in an appealing manner and supported by a very popular scientist. However, the success of the arguments used by the animal rights groups was also due to the very limited awareness of the Italian public on the general issue of invasive alien species. Further, the Italian legal framework does not address the issue of alien species, and does not define an authorisation process for eradications.

The time factor proved decisive for determining the failure of the project. The urgency of implementing the eradication before the grey squirrel could reach the wood belt of the Alps forced us to start the campaign rapidly, without an adequate period for informing the public on the aims of the eradication. The 3-year suspension of the programme allowed the alien species to expand its range to a level that made its eradication unfeasible.

Eradication in mainland areas is strictly time-constrained because it may become non-feasible once the invasive species reaches a certain population level and range. Different from island environments (or other geographically isolated areas) where invasive species cannot expand indefinitely, in mainland areas eradication remains feasible only for a critical period,

whose lapse is difficult, if not impossible, to predict with a high level of certainty (Genovesi, 2000).

In the case of the grey squirrel in Italy, the problem was first reported in 1980, and its eradication became unfeasible in 2000 (Table 1). If the process for arriving to an eradication (decision process, planning, and implementation) had started soon after the species was localised, 20 years would probably have been a sufficient time for its completion. Unfortunately, the local authorities responsible for pest programmes, although repeatedly urged by scientists, wildlife managers, and conservation organisations, did not implement any initiative, and when the NWI decided to directly carry out the trial eradication, time had already expired.

Lessons for the future

Addressing the threats posed by IAS requires a comprehensive approach, based on information, awareness, an adequate legal framework, public involvement in the decision process, commitment of the political decision makers, and adequate technical means. Weakness in a single link of the chain may result in the failure of the entire campaign.

The development of specific human dimension tools, aimed to involve public and to build up consensus on strategies, roles, and responsibilities, should thus represent a priority. For example, public involvement in the decision process for the creation of bio-security agencies with the power to eradicate alien species, or in the definition of national/international strategies to reduce threats posed by biological invasions, can result in more effective action than trying to build consensus for single eradication projects.

Wildlife managers need to be aware of the existence in society of different positions regarding animals, ranging from hunters to animal rights supporters, and to consider these different targets when informing the public on the priorities and actions. Every decision involving animals control or eradication, even if widely supported, may be considered unacceptable by groups or individuals that ethically or philosophically do not agree. In these cases, no scientific evidence on the conservation threats can solve the conflict, and a political decision needs to be taken. In fact, animal rights activists place the no-kill ideal above the ecosystem conservation objective and do not put great emphasis on population and species conservation (Decker and Brown, 1987; Thompson and Lapointe, 1995). Opposition groups can be constituted by a few people with strong motivation. Usually they are prepared to argue their case in court, because litigation often is a more effective way for them to be heard (Thompson and Lapointe, 1995). The only possibility to limit their actions is to design and implement a legal framework that clearly considers the need to eradicate alien species when they threaten ecosystems and native species.

Time is also an important parameter. In fact, the decision process in the case of eradications, different from other controversial wildlife management alternatives (for example carnivore translocations), cannot last indefinitely, especially when addressing mainland biological invasions. A rapid alert mechanism and a clear decision process can determine the success of an eradication project on the mainland.

Table 1 Timetable of the grey squirrel invasion in Italy: main conservation, legal and management steps, and range expansion data.

Year	Milestone	Range (km^2)	References
1948	Introduction of two pairs of grey squirrels at Stupinigi	< 0.1	Currado *et al*., 1987
1970		25	Wauters *et al*., 1997
1979	Last observation of red squirrel at Stupinigi		Wauters *et al*., 1997
1980	First report of the grey squirrel in a regional scientific publication		Baratti, 1980
1981	First report of the species in a national scientific publication		Cagnolaro, 1981
1987	First publication that proposed the eradication of the species from Italy		Currado *et al*., 1987
1990		243	Wauters *et al*., 1997
1992	Resolution signed by international experts on the need to eradicate the grey squirrel from Italy		1st European Workshop on Squirrel
1995	Recommendation to eradicate the species approved by the NWI and sent to national and local administrations		
1995	First plan for the eradication of the species presented by the University of Turin to the local administration		
1997	First article on the replacement of the red squirrel by the grey squirrel in Italy		Wauters *et al*., 1997
1997		380	Bertolino and Genovesi, in prep.
1997	The NWI and the University of Turin produced an action plan for the eradication of the species		
1997	May: start of the trial eradication		
1997	June: animal right groups take the NWI to court		
1997	Resolution signed by international expertise supporting the eradication programme		4th European Workshop on Squirrel
1999	December: NWI judged guilty		
1999	December: The Standing Committee for the Bern Convention approved a recommendation urging Italy to eradicate the grey squirrel		
1999		880	Bertolino and Genovesi, in prep.
2000	May: The NWI produced a strategy for the conservation of the red squirrel in Italy		Genovesi and Bertolino, 2000
2000	July: The Appeal Court fully exonerated the NWI		

Putting people first in a invasive alien clearing programme: Working For Water Programme – are we succeeding?

Simone Noemdoe

Abstract

The development of integrated strategies and programmes to deal with the eradication of invasive alien vegetation is the way to the future. Through the development and implementation of the National Working for Water Programme, South Africa is currently able to put forward a very strong argument for using activities of clearing invasive alien plants as a means to fight poverty. This paper will focus on some of the direct human benefits and the associated challenges.

Introduction

This paper demonstrates the opportunities provided by an invasive alien species (IAS) clearing campaign to uplift and develop communities in South Africa. It will highlight some of the outstanding achievements as well as the challenges of the social development interventions in a multi-departmental integrated environmental development programme.

Alien trees and shrubs invade large tracts of potentially productive land in South Africa. These plant species are capable of invading indigenous vegetation because they originate from similar environments and are thus well adapted to local conditions. In an environment where natural enemies do not occur, they grow faster, mature earlier, and produce many more seeds than native species. This means that they can out-compete indigenous vegetation, resulting in the replacement of the natural vegetation with dense infestations of alien trees.

This has negative impacts on water resources and on the ecological integrity of our natural ecosystems. In South Africa, the total area invaded by woody aliens (estimated at 10.1 million hectares in 2000) is expanding by about 5% per year. If the invaded area is "condensed" to adjust the cover to 100%, the equivalent of about 1.7 million hectares are fully invaded. This is approximately the area of the country's Gauteng Province. It is estimated that the annual use of water by terrestrial woody alien invaders across the whole country is some 3,300 million cubic meters, or around 6.7% of the estimated mean annual runoff for the country.

South Africans and invasive alien plants

It is clear that South Africans and invasive alien plants are co-existing in many communities. Invasive alien plants are part of their landscape and their existence is hardly frowned upon. They are commercially exploited and in most communities where they occur they are welcomed by especially the poor as natural resources to be exploited for their daily survival.

One such example is in the Western Cape Province, where poor households in townships and informal settlements are dependant on wood collected from invading *Acacia longifolia* and *Acacia cyclops* "forests" for construction poles and firewood for cooking and heating. However, these forests also pose some risks to their immediate safety and survival. Criminals use the vegetation as cover to pounce on innocent victims. It invades natural vegetation and threatens natural ecosystems, invading grazing and productive agricultural land.

The Working For Water (WFW) Programme

In response to this problem, the then Minister of Water Affairs and Forestry, Professor Kader Asmal, launched the Working for Water Programme in 1995 as a Reconstruction and Development Programme. The initial objective was to remove alien vegetation from South Africa's catchments and river systems to enhance water supplies, and to create employment opportunities for previously disadvantaged communities.

To date the programme has grown to embrace many additional benefits and spin-offs which arise out of the symbiosis between the fundamental need for action from an ecological perspective, and the need to create jobs in a country with an unemployment rate estimated to be higher than 30%. This multi-departmental integrated initiative, still under the Department of Water Affairs and Forestry (DWAF), has grown and continues to develop, as one of South Africa's "most successful public works programmes."

The WfW Programme has been able to demonstrate its ability to put people first. This is clearly demonstrated in the WfW Programme's operational strategies. It made a fundamental shift from the historical and more conventional approaches to clearing invasive alien plants. Avoiding the easy mechanical, chemical or biological approaches that were implemented on a smaller scale in the past, the WfW Programme developed a cost-effective and efficient integrated invasive alien clearing programme by balancing all the existing methods with the need to uplift and develop people.

Goal and Policy framework

Under the leadership of Minister Asmal, poverty alleviation became the anchor of the WfW Programme and ultimately the following goal and key social development objectives evolved: "The Programme's goal is to bring invading alien plants under control in South Africa within 20 years, in a way that both contributes to the potential use of natural resources and maximises the reconstruction and developmental benefits that are possible from such a labour-intensive environmental programme. The social development objective states that the WfW programme will strive to optimise the social benefits that are possible as a community-based public works programme, by investing in the most marginalised sectors in South African society and enhancing their quality of life. Its economic objective states that the WfW Programme will aim to develop the economic benefits (from land, water, wood and people) from clearing these plants, by facilitating economic empowerment and the development of secondary industries, and to play its part in protecting the economic integrity of the productive potential of the country".

Cabinet showed its commitment to this clearing programme by granting the Working for Water programme US$112 million from the Poverty Relief fund. In addition, R401,446 million (US$96 million) has been allocated through the annual budget votes through the departments of Water Affairs and Forestry, Land and Agriculture, Environmental Affairs and Tourism and Social Development over the last five years. This funding and institutional support enabled the WfW Programme to develop the strategies and systems to have an average annual employment of 21,000 people. It is estimated that each worker employed support up to seven or more beneficiaries per household.

Transformation and Empowerment

Empowerment of the historically disadvantaged is a huge challenge in this transitional society. The WfW Programme focused implementation on several key principles demonstrating its commitment to poverty relief and people development. Projects are not approved unless labour intensive clearing or rehabilitation methods are used. Unemployed contractors and the workers are selected from the most marginalised and poor in the community. Single female-headed households rank the highest for job opportunities. This is also balanced with the employment of youth and disabled generally marginalised and in dire need of development opportunities. Employment statistics for the 1999/2000 financial year demonstrates this clearly, with 56% women, 23% youth between the ages of 16 and 25 and 1% disabled having been employed.

The programme also acknowledges that creating disposable household income does not automatically translate into economic emancipation. Encouraging a culture of life-long learning and pursuing accreditation, an integrated skills development programme is a core part of the package you sign up for when taking a job with the programme. Its education and training programme's primary focus is functional and technical skills training for invasive alien clearing operations. In addition emphasis is placed on essential life- and business skills development. During the past year 884 emerging contractors were trained (33% were women, 10% youth and 0.5% disabled. Fifteen percent of these are collective business models).

Training and development programmes are developed on the principles of an exit strategy for contractors and workers. The Emerging Contractor Development Programme aims at transferring skills that will enable workers and contractors to tender for independent clearing contracts with landowners. They could also choose to get involved in the service and hospitality industries like selling consumer goods and the tourism industry. The Secondary Industry Development Programme will focus on skills and market development towards the long-term sustainability and survival of workers.

The programme further developed a partnership with the Homeless Peoples Federation who works with local groups actively encouraging workers to contribute towards savings schemes. Contractors and workers are encouraged to save. Training in personal finance and budgeting is a core component of the savings programmes. Groups are encouraged to explore enterprise development as an alternative source for future income. Group savings are currently used mainly for funding education and the purchasing of goods and services.

Transformation and change is not only required in terms of people development. The programme is therefore fostering a culture of collective governance. The programme and its implementing agents work closely with local communities. Civil society is encouraged to own the problems of clearing invasive alien plants individually and collectively. Programme management insists on local organisational participation and the established steering forum at project level serves as a project reference group, guiding the implementation process and keeping it relevant to local conditions.

Social relevance

The WfW Programme constantly strives for social relevance, integrating key initiatives demonstrating this commitment to the workers and the beneficiary communities. Development interventions are not entered into unless there are clear long-term sustainability factors built into the interventions. Key examples of some of the programmes are:

- **HIV/AIDS Programmes.** In its second year of implementation, an HIV/AIDS workplace and community-based programme is implemented with the total commitment and support from the Department of Health. Core activities are an awareness programme on the spread of HIV/AIDS, condom distribution and facilitating access to voluntary HIV/AIDS counselling and testing.

- **Ex-Offender Reintegration.** Another such challenge is dealing with sustainable solutions to crime in a society where up to 70% of offenders are back behind bars a short period after their release. Working closely with security forces the WfW Programme is actively involved in breaking the cycle of crime by employing ex-offenders. To date the programme has employed over 300 ex-offenders on short-term contracts with a special skill development programme to create long-term alternative options for the ex-offenders.
- **Primary Health Care Services.** Working closely with local health care service providers, the Programme facilitates and advocates the extension of primary health care services to workers and communities. It focuses on access to sexual and reproductive health services, information, education and communication programmes on nutrition, personal hygiene, diarrhoea and malaria and tuberculosis in the areas affected by this.

Challenges in putting people first

Location of alien invasive plants and poverty

The poorest and most marginalised households and the spread of invasive alien plants targeted are often not in close geographic proximity. This impact on the clearing cost, as the infrastructure inputs are higher, makes less money available to employ more people. Communities are plagued with high numbers of unemployed and to equitably spread the resources for maximum target reach across the country, the programme only employs small numbers from the available labour pool in communities. Contractors and workers employed are envied for their opportunities. This strategy puts pressure on project managers to employ more workers.

Social responsibility vs profits

There is an inherent conflict between individual profit and business development and collective financial benefits and growth. The current contractor development system is geared towards highly productive and efficient teams that will be able to run clearing operations under any conditions. Contractors have to find a balance and this translates to a high worker turnover in some areas. Workers are then short-changed in terms of the length of their contract period and missed opportunities to develop their skills for alternative employment options. Individual and collective contractors also battle to reinvest in the business and have expressed a need for access to micro credit to grow their business. Workers, on the other hand, expect that all profits be shared among the group as bonuses.

Making ends meet

The money earned by contract workers is a stipend toward the collective household income. Workers are constantly locked in a battle to meet their basic needs. This is exacerbated by a proliferation of micro lenders providing easy access to short term credit at high interest rates reducing their ability to accumulate savings.

Training and development capacity

To be able to access training services to the scale required by the programme is a slow process. Loss of productivity and the risks of injuries on duty were very high at the start of the programme. The majority of the workers are unskilled when they start working on the projects. It is therefore a challenge to develop holistic development programmes tailored to the different skill levels required by the programme.

Bureaucratic institutional systems

Institutional development and transformation are slow processes and this is often in conflict with the financial year spending cycles. In many areas local government and partner organisations are weak and struggling with the existing demands on its services and not always capable of taking on more responsibilities. The Department of Water Affairs and Forestry procurement systems are not capable of dealing with processing payments to over 884 contractors within a 20/21-day cycle. This has a negative impact on the Emerging Contractors and workers as they face a constant cycle of late payments.

Developing partnerships and agreeing on boundaries between the different line departments and organisations involved in the programme is a slow process. This process is in direct conflict with the short time frames within which the funds should be spent.

Gender issues

Balancing the selection criteria within the South African socio-political context is still a difficult process. Women as the primary beneficiaries are facing difficulties in having their status asserted by the programme, but still living and working in a mainly paternalist male dominated society.

Conclusion

Despite these challenges the WfW Programme continues to develop more clearing and rehabilitation projects that will increase the employment opportunities at local level. Working with partners' solutions is sought to improve implementation strategies. Implementing research programmes will, it is hoped, find answers to the more complicated social, economical and political challenges encountered when putting peoples' development first.

Both households getting direct benefits and those not directly benefiting in local communities, partner organisations and other government departments, hold the programme in high esteem. Municipalities report increased payment for water and electricity now that the WfW projects are implemented in their areas. The community in the Encobo area in the Eastern Cape Province used their collective profits to invest in a school building. Women report that they are now able to provide for the basic needs of their children like food and school fees. Many are able to able to invest in improving their houses. One can therefore say that the Working for Water Programme is a shining example and model programme in terms of being able to get development funds into the right hands.

The WfW Programme has been able to lead by example in developing integrated, multi-stakeholder, and multi-departmental implementation of education, legislation, and policy and grassroots implementation models. For South Africans, clearing invasive alien plants has become a vehicle to drive out poverty and create sustainable community development options.

A case study of human dimensions in invasion and control of alien plants in the personnel villages of Kruger National Park

Llewellyn C. Foxcroft

Abstract

The mission statement of the Kruger National Park is "To maintain biodiversity in all its natural facets and fluxes, and to provide human benefits in keeping with the mission of the South African National Parks (SANP) in a manner which detracts as little as possible from the wilderness qualities of the Kruger National Park". In keeping with this statement and accepting that invasive alien organisms violate this basic objective, the threat of invasive alien plants is considered the greatest threat to the conservation of biodiversity in the Kruger National Park (KNP). Alien plants originate and invade the KNP largely from upstream sources in the catchments. However, a paradigm shift in the management of the KNP, particularly in terms of alien biota, has led to greater understanding and support of the seriousness of controlling these species within rest camps and personnel villages inside the National Park. SANP recognises the role it must play as a forerunner in the effort to control alien species, educate the general public as to the threats posed by these plants and become a role model in conservation circles. In keeping with the above, a policy document was approved by the Kruger National Park Management Committee, which determines the manner in which alien plants in restcamps and personnel villages are defined and controlled. Nevertheless, the implementation of this policy is not as simple as it may seem, particularly where human interactions come into the equation. This paper presents a specific case study of the situation faced in the control of invasive alien plants over the past 50 years, within the personnel residences (focussing on Skukuza personnel village) and restcamps in the KNP.

Introduction and background

The Kruger National Park (KNP) is situated on the eastern side of the Mpumalanga and Northern Provinces of South Africa. Situated between the latitudes of 20°20' S and 25°31' E, it covers an area of 1,948,528ha. It runs 360 kilometres from north to south along the Lebombo Mountain range forming the international boundary between South Africa and Mozambique. It is transversed by seven major rivers, the northernmost of which is the Limpopo River, also forming the northern boundary of the KNP, while the Crocodile River forms the southernmost boundary of the KNP. All major river systems have their origin in the higher-lying escarpment to the west of the KNP (see map).

Invasive alien plants were probably already within the Sabie Game Reserve (proclaimed in 1898, in the now southern KNP) and Shingwedzi Reserve (proclaimed in 1903, in the now

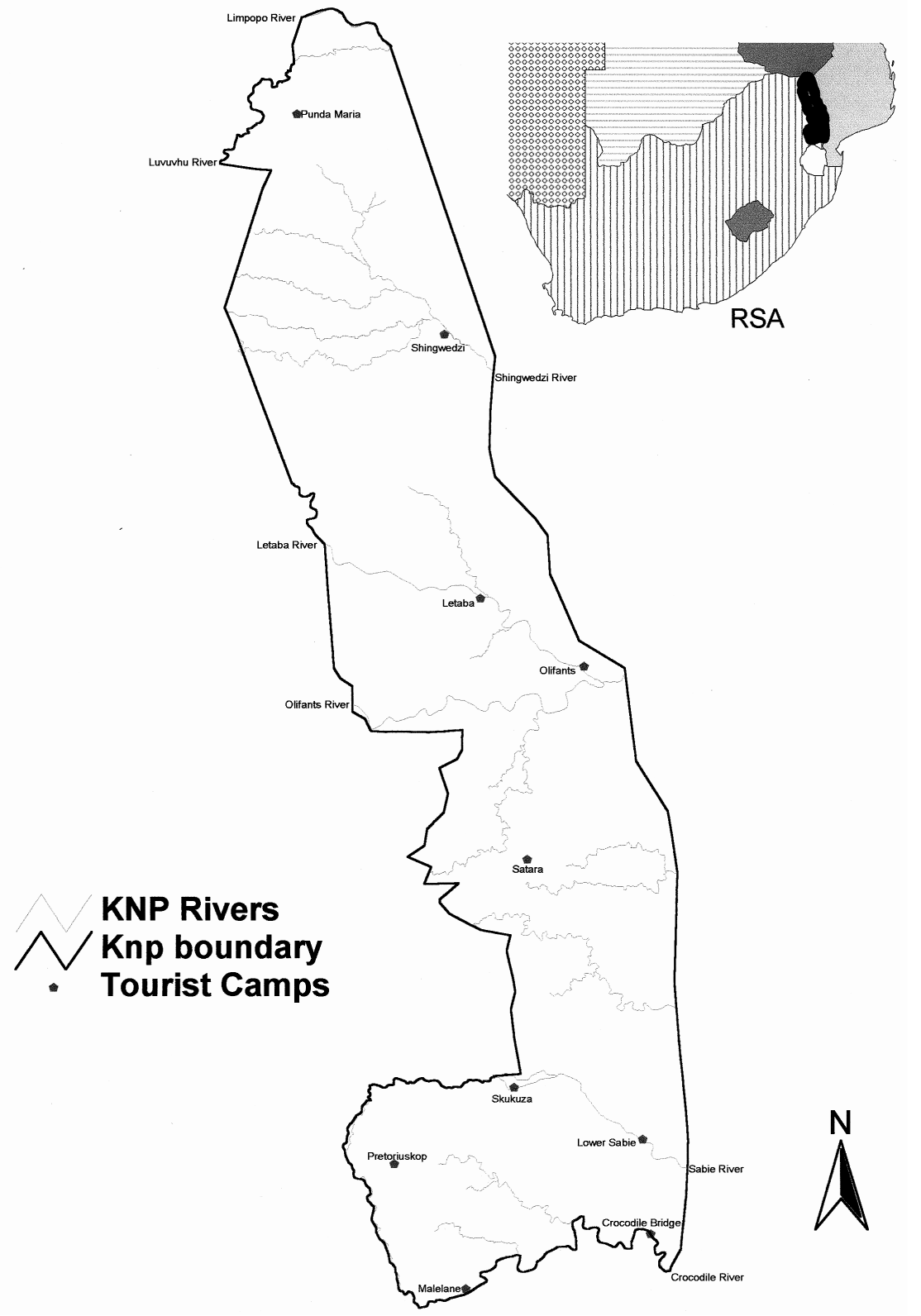

Fig. 1 Kruger National Park

northern KNP). Similarly, the impacts or threats posed by alien biota, particularly plants, were clearly not recognised in 1926 when the KNP was proclaimed.

In the early days, there was no prohibition on the introduction of alien species (MacDonald, 1988) and various exotic tree species were planted in newly established restcamps (Bigalke, 1947). MacDonald (1988) states that several invasive plant species (shrubs and others) were originally introduced intentionally into restcamps and staff gardens. By 1951, Codd (as cited in MacDonald, 1998) listed 17 species that had become invasive through these intentional introductions. On the other hand, unsuccessful attempts to introduce an alien species for cultivation are also recorded from 1930, where efforts were made to introduce the tsama mellon (*Citrullus lanatus*) (MacDonald, 1988).

Later, a low-density population of people who resided in the area were permitted to keep small herds of cattle, sheep and goats. However, in 1938, in an effort to prevent the spread of foot-and-mouth disease all domestic livestock were destroyed and local populations dwindled as the people emigrated to areas outside of the KNP (MacDonald, 1998). Evidence of alien species left by these people are *Ricinus communis* (castor oil plant) which invades the riverine areas throughout the KNP, as well as isolated dense stands of *Opuntia ficus-indica* (prickly pear). Currently, the alien plant problems posed by the local villages on the boundaries of the KNP include that of *O. ficus-indica*, of which the fruit is utilised, *Cereus jamacaru* (queen of the night) and *Agave* species (sisal) which are used for protection and fencing. Other alien plant tree species that are planted include *Delonix regia* (flambouyant) and *Tecoma stans* (yellow bells), which are primarily used for shade trees, in areas which have been severely denuded of trees for firewood and carvings sold to tourists. Many species are planted for beautification, including *Lantana camara* (common lantana), *Senna* species (cassia), *Sesbania punicea* (red sesbania) and various creepers.

Discussion

Problems experienced as a result of intentionally introduced species escaping into the surrounding environment

The Skukuza personnel village and restcamp (the larger portion of which was built in the 1950s) is situated on the banks of the Sabie River, regarded as one of the most diverse rivers botanically, in South Africa (Cilliers, *et al.,* 1996; Lotter, 1997) and has been a focus of contention since control programmes were first instituted. In 1953 Obermeijer recorded the first known *Opuntia stricta* (sour prickly pear) plant in a resident's garden (Zeller, 1996). Later this plant was found to have been spread by baboons (*Papio ursinus*) and elephants (*Loxodonta africana*) covering an area of 1,000ha by 1980 and expanding to 19,000ha by 1990 (Lotter and Hoffmann, 1998). Currently the infestation covers an area of approximately 35,000ha, with isolated plants known to exist outside of the 35,000ha range. In order to accurately map, find and control the plants, an area of approximately 66,000ha would need to be surveyed.

Ecological impacts of this noxious weed include densification to an extent where clumps become impenetrable and extend over several hectares (Hoffmann *et al.,* 1998; Lotter and Hoffmann, 1998). Associated with this scale of infestation are the well-known impacts of invasive species, such as the exclusion of indigenous fauna and flora and altered biomass of the grass layer. The altered grass biomass represents a change in the associated fire regime of the fire dominated savannahs of the KNP as well as the competition of the introduced species preventing seedling establishment of some of the indigenous tree species, such as *Spirostachys africana* (tamboti).

Other alien species found to have spread from the Skukuza staff village were *Pistia stratiotes* (water lettuce), which escaped from a fish pond into the Sabie River and infested the river for 17 kilometres downstream (MacDonald, 1998). Today, after extensive chemical control efforts

and two major flood events, the infestation has cleared from the Skukuza area and now occurs further downstream at Lower Sabie dam (Cilliers *et al.,* 1996). *Salvinia molesta* (kariba weed) was also found on the Sabie River and on a natural spring near Pretoriuskop restcamp, which was thought to have been spread by the re-introduction of an indigenous fish species to the dam, which contained fragments of the aquatic weed originating from the Sabie River (MacDonald, 1998)

Following the spread of these species, efforts then focussed on the control of well-known invasive plants such as *L. camara* and *O. stricta* and others in the personnel village. This was primarily due to the fact that it could be well demonstrated that *L. camara,* which is reported to have spread from plantings in restcamp gardens (MacDonald, 1998), had invaded all major rivers in the KNP and *O. stricta*, the area around Skukuza. Nevertheless, efforts to clear alien plants from personnel gardens at this stage were already met with resistance.

Control measures to prevent species from escaping from the staff village

In 1972 a list of alien plants prohibited in the KNP was published in the KNP Code of Conduct. This list stated that these plants were not to be planted in any garden or restcamp in any National Park and that where they were already present, they were to be removed immediately. Species included *Melia azedarach* (syringa), various *Opuntia* species, *L. camara*, various *Acacia* species, *Eichhornia crassipes* (water hyacinth), *Psidium guajava* (guava), *Agave* species, and *Ipomoea purpurea* (morning glory) (U. de V. Pienaar, 1972).

By 1984 a more comprehensive list of alien plants found in gardens and requiring removal was drafted. The Code of Conduct was updated and included in this list were all the species that were declared prohibited by the South African Conservation of Agricultural Resources Act, (Act 43 of 1983). By this stage the Code of Conduct stated that all species that do not occur naturally in the KNP are considered exotic. It also stated that "most of the important invader species found in the park have spread from gardens and the measures applied to control these plants cost tens of thousands of Rand annually". Further, a number of laws applicable to the planting of exotic species in the KNP were formalised, as well as the fact that the gardens would be periodically inspected by the Alien Plant Section Personnel. This list also contained many exotic creeper species, which are well-known invaders in other parts of South Africa, such as *Macfadyena unguis-cati* (cats claw creeper), *Solanum seaforthianum* (potato creeper), and *Aristolochia elegans* (Dutchman's pipe).

Although recognised in policy as a serious threat to the integrity of the KNP, limited resources were allocated to the control of alien plants in general and specifically in the staff villages, before they became a problem and infested the Sabie River and surrounding areas. Even so, removal of aliens was resisted by occupants of staff houses and negative connotations were made with the Alien Plant Section. Residents felt threatened and resisted the thought that the gardens that they had put so much time and effort into would be destroyed. Although further efforts were made to inform and educate the residents that the plants posed a serious risk to the KNP, control efforts continued under difficult circumstances.

This, together with the other clearing operations (chemical control of *P. stratiotes* on the Sabie River, clearing of *L. camara* along the riverine fringes of the Sabie River and herbicidal control of the growing *O. stricta* infestation), and a shortage of resources and manpower, resulted in little being done to follow-up and implement the control of alien invasive plants in staff villages. Consequently, a substantial increase in the number of plant species likely to escape from the Skukuza village and species with potential to escape was observed over the next two decades.

In an effort to be proactive for the first time and develop a consolidated plan of action, a survey was undertaken in 1999 in the Skukuza personnel village, in which a total of 234 species of alien plants were recorded. Many of the gardens belonging to members of staff in the Skukuza personnel village resembled suburban gardens of subtropical regions in the rest of the country and definitely did not portray the atmosphere of the indigenous species in the National Park. It was the same pattern of plants that stimulate the human senses elsewhere that led to the progressive development of non-indigenous lush subtropical gardens, with most of these alien plants having no functional use in Southern African landscapes. Throughout the staff village (approximately 270 houses), 90% of the gardens feature the same species (e.g. gingers, sword ferns, wandering Jew). It appears that due to the small and closely-knit community, certain species were passed around and planted from one garden to the next.

This survey led to the development of a draft policy document for the control of alien plants within personnel villages, other staff residences and restcamps of the KNP. The main aim of the policy is to systematically phase out all alien plant species of the KNP, initially working on the most invasive species and gradually moving through to non-invasive ornamental plants. The policy documented the species recorded, as well as the species declared as weeds by the aforementioned Conservation of Agricultural Resources Act, and stipulated prohibited species and the prohibition of the use of these species in gardens and camps. As a number of species in the policy constitute a major component of staff gardens and are not all equally invasive, a phased approach has been adopted. Thus, the 60 most serious potential invaders of the 234 listed species were prioritised into three categories, from intolerable to undesirable. These priority species were selected on their ability to reproduce rapidly, either by seed or vegetatively, and the threat they pose by growing near the Sabie River. The document also outlines the procedures to be followed in control operations, namely that only priority one plants will be removed initially, until the whole village is cleared of these specific plants and then only will the next priority plants be controlled. This approach allows parts of the garden to be cleared, leaving some vegetation and allowing time for the plants removed to be replaced with indigenous alternatives. In vacant gardens, all alien plants are removed before the new occupant moves in.

After being approved by the Management Committee for KNP in November 1999, the Alien Biota Section was given the approval to implement clearing operations. However, much resistance was met with from some personnel. Before the implementation of the control efforts, time was put into the awareness component, to allow the people an opportunity to remove the plants themselves, but also to become aware of the threat posed by the plants. However it is recognised in retrospect that the efforts made were not sufficient and more time should have been spent on this before implementing the programme. Emphasis is placed on the fact that although the people live in a village, they are in the privileged position of residing within a National Park and that the control of these plants is essential for the conservation of the biodiversity of the KNP.

Potentially invasive species growing in the personnel village include plants such as *Leucaena leucocephala* (leucaena or ipil ipil tree; Fabaceae). Although only a few plants were present in the staff village, they were found at the bottom end of a garden, adjacent to the Sabie River floodplain, with large numbers of seeds spreading into the neighbouring garden and onto the floodplain. Other families which are represented include the Commelinaceae, having semi-succulent leaves and stems with the ability to propagate from stem cuttings or pieces thereof. Examples include *Callisia elegans* (wandering jew), *Tradescantia zebrina* (wandering jew), *T. pallida* (purple wandering jew) and *Rhoe spathacea* (boat plant) being the most established and problematic. Dispersal of these plants has been passive, spreading into the damp tributaries of the Sabie River from the environs of the gardens, and human assisted, being dumped over the boundary fence as garden refuse and spreading from there. Another family that poses a threat is the Crassulaceae, represented by *Bryophyllum* species and also the true Cactaceae. A single

Pereskia aculeata (Barbados gooseberry) plant was observed in a pot plant container. *P. aculeata* is probably the most pernicious plant invader in Kwazulu-Natal (G. Nichols, pers. comm., 1999). During the severe floods in February 2000, where many of the gardens in the Skukuza personnel village were flooded, this plant specimen was washed into the river, and now lies as an immanent threat somewhere in the Sabie River system. The same concern exists for the seeds of the aforementioned *L. leucephela* species and many other exotic species, which were washed into the Sabie River during the flooding of the staff gardens.

The most contentious plant family in the village with regard to clearing operations is the Zingiberaceae family (gingers). Represented by the genera *Hedychium* and *Alpinia*, these beautiful plants are producing viable seeds and have the potential to invade the moist riverine systems of the KNP, are widespread throughout staff villages and cover large portions of the gardens. It is with reference to this family that most resistance is met during control work, due to the fact that these species are quick growers, with beautiful flowers and provide effective screens between gardens. This is especially important in a small community that works and lives in close proximity to one another and regards privacy at home as especially important.

Economic implications of the control of alien invasive species in the KNP

Currently, the annual SANP budget for controlling alien invasive species in the KNP amounts to R 660 000 (US$157,600). Herbicidal control measures for the control of *O. stricta* in 1998 alone amounted to R323 000 (US$77,133) (half of the section's annual budget). Although grossly under-budgeted, the Alien Biota Section focuses on integrated management programmes wherever possible; for example the *O. stricta* infestation is controlled through the use of registered herbicides and biological control.

Previously, large proportions of the KNP Alien Biota Section's funding were utilised to control *L. camara* infestations along the Sabie River, which were reaching serious levels of dense infestation. Therefore, little work was done in staff villages and restcamps, due to the shortage of manpower and resources and the antagonistic attitude of residents. However, through the development of the South African Government's Department of Water Affairs and Forestry, Working for Water programme, which also includes partnerships with other government departments and the Royal Netherlands Embassy, large numbers of temporary personnel are employed to clear the riverine fringes of invasive alien species in the KNP and in the catchments. The total funding spent by Working for Water in the KNP since 1997 stands at R 13.5 million (US$3.2 million), and has approved a further amount of R 2.8 million (US$668,640) for the 2000/2001 financial years. This has enabled the KNP Alien Biota Section to redirect its emphasis into becoming proactive and controlling the species in staff villages, before they spread into the neighbouring areas and riparian zones.

Most of the herbicidal control programmes against aquatic alien plants have been stopped largely due to budgetary constraints. Currently a long-term programme for controlling aquatic weeds biologically is implemented, for example water lettuce (*Pistia stratiotes*) which is found in various parts of the KNP, but most predominantly at Lower Sabie dam. Further complications in mechanical and chemical control of aquatic alien species are the inherent dangers from hippopotamus (*Hippopotamus amphibius*) and crocodiles (*Crocodylus niloticus*) faced by the worker squad, when entering these areas by boat and on foot.

Conclusions and recommendations

People have an intrinsic attachment to their gardens and the species represented there. This attachment is very personal and highly valued by people. The longer-standing personnel, who

have lived in the KNP for some 20–30 years, are extremely resistant to the removal of these plants, as they have spent much time on their gardens. Relatively newer people in the KNP generally cooperate and allow the plants to be removed. Due to the very unique position and nature of living in a National Park, people employed and living in the KNP have few recreational opportunities, and therefore it enhances the great pride in the gardens and time and effort spent in tending them. This personal attachment to the gardens is possibly emphasised further in the KNP, as they resemble an "oasis" in the relatively drier, harsh landscape of the KNP. Further, houses in the National Parks are rented for the period of service, which is leading to a situation where people are increasingly reluctant to invest in redeveloping the gardens after being cleared of alien species and therefore strongly resist the removal of any plants.

Unfortunately a negative connotation has been formed with the Alien Biota Section, due to the persistent manner in which the control efforts were done in the past and the relatively low priority status afforded to the alien plant section by park management. Although efforts have been made to address this issue and the section is now represented at higher management and committee levels, the change of attitude towards the section is a slow process.

It also appears that a number of misperceptions may exist, and are the basis for arguments against the control of alien plants. Many people believe that there are no suitable indigenous plants to replace the exotic species. This has proved to be unfounded, as discussions with the Skukuza Indigenous Nursery (Davies, pers. comm., 2000) provided a substantial list of indigenous species that may be used to replace the alien species removed. These species will effectively replace and fulfil the same function as the alien species, will attract an abundance of birdlife and require less irrigation, as they are adapted to the harsh, frequently dry environment of KNP.

It is an important fundamental principle to ensure that where working with personnel gardens or in any situation where there is personal attachment involved, high standards of supervision at ground level is maintained to prevent accidental removal or damage of indigenous species and incorrect control methods. Should mistakes occur, an immediate and almost irreversible negative reaction and feeling towards alien control measures will result. This is possibly an aspect that the KNP Alien Biota Section neglected to address previously and which also probably enhanced the negative connotation of the section.

It further appears that although efforts are made to educate and inform the residents, due to negative perceptions of the damage the section causes to their gardens and other reasons, a unwillingness to cooperate with the control of these plants prevails. This is continued even though invasive alien plants are regarded as the greatest single threat to the integrity of the KNP (Lotter and Hoffmann, 1998; Anon., 1997). The control of alien plants in staff villages, which have already caused a number of species to escape into the natural surroundings and cost large sums of money to combat, should be a priority and controlled before further species become out of control, which is in the best interests of the National Park and its goals. Fortunately, at the present time, this perception is changing and the personnel generally cooperate and assist in the removal of alien species. To further alleviate this problem, education and awareness efforts for KNP staff about the threats alien plants pose need to intensified and expanded.

Lessons learned through the implementation of control programmes in the staff villages, however obvious, have indicated important aspects to consider when working in such a unique community or situation which is relatively remote and offers few other recreational opportunities. It is important to ensure that species are removed before becoming widespread. Beyond easier control and lower levels of seed development etc., people are more willing to cooperate while there are still relatively few individuals in the gardens. Once common throughout the village, there is enormous resistance. Species which were never regarded as invasive and were allowed in the staff villages often became invasive at a later stage, due to the lack of information regarding the invasive potential of species and also a lack of vigilance in controlling the species before it escaped into surrounding environs. Of paramount importance

is the awareness and education of people with regard the serious problems posed by invasive species and the importance of preventing them from establishing in an area such KNP.

The positive outcome of the efforts over the past 50 years is the trend of increasing support for alien plant control in KNP. Further, the role and importance of alien species is being increasingly recognised by scientists and ecologists in the KNP scientific services division and cognisance is being taken of the impact of the species on the indigenous fauna and flora communities.

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Human dimensions of invasive alien species in Sri Lanka

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Abstract

Non-native plants and animals are invading the natural and agricultural ecosystems of Sri Lanka, threatening the country's biodiversity. Human intervention has been identified as the major factor that has influenced the introduction and spread of the invasive alien species in this island nation. Seed exchange between botanic gardens and intentional introductions of plant species for their horticultural and soil conservation values are the major modes of introduction and spread of invasive plants alien to Sri Lanka. Several attempts have been made to eradicate or manage invasive alien plant populations with community participation, but with little success. Poor coordination of programmes and insufficient involvement of major stakeholders are the major constraints to the successful implementation of the management programmes for invasive alien species in Sri Lanka. The need for a national invasive alien species action plan for the country is highlighted.

Introduction

Alien species are invading the natural and agricultural ecosystems of Sri Lanka, causing tremendous damage to available resources. Generally identified as exotic, alien, non-native or non-indigenous species, and in special occasions as weeds, these invasives get into our ecosystems by various means. Fast-growing alien plants encroach from populations established outside target ecosystems. They escape cultivation and become agricultural pests, infest lawns as weeds, displace native plant species, reduce wildlife habitat, and alter ecosystem processes. Across Sri Lanka, invasive alien plants and animals have become a serious threat to native species, natural communities, and ecosystem processes. They also exact a costly toll from human economies that depend on resources and services provided by healthy ecosystems. Examples include clogging of important waterways by aquatic invasives, leading to increased costs in maintaining irrigation schemes.

Factors which make the threats posed by IAS very important to Sri Lanka are: small size of the country; its island nature and developing status; an evolutionary history which has resulted in high levels of species endemism in the southwestern part of the country; and the current highly threatened status of many endemic species and their habitats.

Records show that many species of alien biota (especially plants) were introduced to Sri Lanka during the past 500 years, a period during which the country was subject to colonial rule, commencing with the Portuguese, followed by the Dutch and finally by the British up to 1949. Information from this era shows that most introductions were intentional. In contrast, current trends suggest an increase of unintentional introductions, reflecting perhaps the change in the

drivers of IAS spread which have taken place over the past fifty years. The emerging interest in IAS and their impacts on biodiversity can be directly attributed to the rising levels of environmental consciousness among the general public and more specifically to awareness of the need to preserve the biological heritage of the country in the face of inevitable development pressures.

This paper will present an overview of the human dimensions of IAS in Sri Lanka, using examples and emphasizing threats to preservation of native biodiversity. It will discuss the emerging scenario for addressing issues of IAS at both national and regional scales and recommend priority interventions.

An overview of the human dimensions of IAS in Sri Lanka

Observations made over the past four years have documented 34 species of invasive alien biota, consisting of 13 animal species (Table 1) and 21 plant species (Table 2). Twelve are aquatic and 22 are terrestrial.

Table 1 Invasive alien fauna in natural ecosystems of Sri Lanka.

Invasive species	Distribution	Affected ecosystems
1. Rainbow trout *Oncorhynchus mykiss*	Montane Zone	Streams
2. Clown knife fish *Chitala chitala*	Lowland Wet Zone	Tanks, ponds, slow-flowing rivers, marshes.
3. Plectosomus catfish *Hypostomus plecostomus*	Lowland Wet Zone	Tanks, ponds, slow-flowing rivers, marshes.
4. Guppy *Poecilia reticulata*	Island-wide	Tanks, ponds, slow-flowing rivers, marshes, streams.
5.Tilapia *Sarotherodon mossambicus*	Island-wide	Tanks, reservoirs, slow-flowing rivers, marshes.
6. Snake-skin gouramy *Trichogaster pectoralis*	Dry and Intermediate Zones	Tanks, reservoirs, marshes, streams.
7. Golden apple snail *Pomacea canaliculata*	Lowland Wet Zone	Tanks, ponds, marshes
8. Giant african snail *Achatina fulica*	Island-wide	Natural and managed terrestrial habitats
9. Slug *Laevicaulis alte*	Island-wide	Natural and managed terrestrial habitats
Slug 10. *Semperula maculata* 11. *Semperula siamensis*	Island-wide	Natural and managed terrestrial habitats
12. House rat *Rattus rattus*	Island-wide	Natural and managed terrestrial habitats
13. Domestic/feral buffalo *Bubalus bubalis*	Island-wide	Forests

Table 2 Invasive alien flora in natural ecosystems of Sri Lanka.

Invasive species	Distribution	Affected ecosystems
1. *Annona glabra*	Lowland Wet Zone	Coastal lagoons marshes
2. *Salvinia molesta*	Island-wide	Tanks, ponds, marshes, streams
3. *Eichhornia crassipes*	Island-wide	Tanks, ponds, marshes, streams
4. *Lantana camara*	Island-wide	Scrubland, degraded open forests
5. *Ulex europaeus*	Montane Zone	Montane forests, wet pathana grasslands
6. *Eupatorium riparium*	Montane Zone	Montane forests
7. *Cestrum aurantium*	Montane Zone	Montane forests
8. *Prosopis juliflora*	Arid Zone	Thorn scrublands
9. *Opuntia stricta*	Arid Zone	Thorn scrublands
10. *Clidemia hirta*	Lowland Wet Zone	Rainforests
11. *Swietenia macrophylla*	Lowland Wet Zone	Forest edge
12. *Mimosa invisa*	Lowland Wet Zone	Forest edge
13. *Dillenia suffruticosa*	Lowland Wet Zone	Forest edge
14. *Mimosa pigra*	Intermediate Zone	Riparian areas
15. *Leucaena leucocephala*	Intermediate Zone	Dry-mixed evergreen forests
16. *Clusia rosea*	Sub-montane Zone	Rock outcrop forests
17. *Parthenium hysterophorus*	Dry and intermediate	Fallow fields, marshy areas
18. *Wedelia trilobata*	Wet and intermediate	Forest edge
19. *Myroxylon balsamum*	Wet and intermediate	Dry-mixed evergreen forests
20. *Alternanthera philoxeroides*	Island-wide	Fallow fields, marshy/riparian areas
21. *Hydrilla verticillata*	Island-wide	Streams, canals and marshes

Most deliberate introductions made during the colonial period were for agro-economic and forestry purposes. Today, some of these exotic plants (mainly tea, rubber, coconut and some timber plants) play a vital productive role in the country's economy. However, many other species of alien biota introduced during the colonial period have invaded natural ecosystems, or spread rapidly in human-modified ones, and caused economic, ecological and most likely social problems.

It appears very likely that macroeconomic policies (e.g., free market policies, liberalisation of the financial sector, and increasing the share held by the private sector in the national economy) pursued by successive Sri Lankan governments since the late 1970s have facilitated an increase in entry of IAS to the country. Specifically, recent efforts to diversify the agricultural sector have resulted in private institutions and NGOs attempting to import alien organisms for agricultural purposes. For example, importation of horticultural plants (vegetables and ornamental plants) for commercial cultivation has led to the introduction and spread of several invasive molluscs, some of which are yet to be accurately identified. Alien species have been introduced without adequate screening and evaluation procedures; even when potentially harmful effects of IAS are known, they have been ignored for short-term economic gains. For instance, the ornamental fish trade has led to the spread of several species

of invasive alien fish as well as the golden apple snail (*Pomacea* spp.), a serious pest of rice (Bambaradeniya *et al*., 1998; Bambaradeniya *et al*., 1999).

Some historical and cultural practices have also facilitated the spread of alien biota with invasive tendencies in the island. The domestic buffalo (*Bubalus bubalis*) imported to Sri Lanka from South and South-east Asia since historical times for animal husbandry and agriculture are extensively used in rice cultivation for land preparation. During the fallow period of rice cultivation, rural farmers release the domestic buffaloes to the wild and recapture them during the next cultivation season. This has resulted in the domestic buffalo interbreeding with native wild water buffaloes, leading to large herds of feral buffalo that have become a serious threat to native ungulates in forest ecosystems throughout the country. More generally, the alien domestic animals (i.e., cattle, pigs, cats, dogs) in Sri Lanka are not properly managed, especially in rural areas closer to natural or semi-natural ecosystems, where these animals escape into the wild and form feral/stray populations, thereby causing problems to native biota.

Links between IAS and local resource uses also exist. Traditional practices such as weaving of mats, bags, wall hangings, and production of some types of handicrafts, use species of alien reeds and grasses which are invasives of wetlands and fallow marshy land. This points out that economic gains through use of a few IAS in a developing country such as Sri Lanka cannot be overlooked easily. Of particular concern is the socio-economic impact of IAS on Sri Lanka's extensive and economically-important coastal and marine ecosystems.

Urbanization and infrastructure development (especially roads, canals and power line access corridors) are two of the most visible processes of development in the country, but also facilitate the spread of IAS. Urban wetland ecosystems such as those in and around Colombo (the largest city of Sri Lanka) are dominated by IAS. The growth of the horticultural trade (an important source of revenue for the export-based private sector) is clearly linked to life styles in centres of urban populations where houses and gardens are increasingly home to alien plant, fish and invertebrate species. Roadside weeds already account for a large number of alien plant species, and the present upsurge of road-building throughout the country only serves to exacerbate this problem.

Developments in the agricultural sector, for example the Green Revolution, have led to significant losses in diversity from several hundred land races of rice to just a few dominant varieties accompanied by various new weeds and insect-pests. The initial resistance of modern varieties induces farmers to their exclusive use, but subsequent generations become more vulnerable to pests and diseases, resulting in serious effects on the stability of farming systems.

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. It is important to note that plants that are now invasive or weedy once appeared to be non-invasive when their populations were small or they were found only in habitats influenced by people.

Introductions through botanic gardens

Exchange of seed material between countries, especially through botanical gardens, has been one of the major modes of deliberate introduction of alien plant species into a country or an ecosystem. *Antigonon leptopus*, *Aristea ecklonii*, *Cestrum aurantium*, *Clidermia hirta*, *Clusea rosea*, *Eichhornia crassipes*, *Chromalaena odorata*, *Lantana camara*, *Miconia calvescens*, *Myroxylon balsamum*, *Prosopis juliflora*, *Taraxacum officinale*, *Tithonia diversifolia*, *Ulex europaeus*, and *Dillenia suffructicosa* are the major invasive alien plants that have been imported to Sri Lanka intentionally through the Royal Botanic Garden at Peradeniya (Wijesundera, 1999). Among these, human intervention has facilitated the spread of several invasive plant species within the country.

Water hyacinth (*Eichhornia crassipes*) was introduced to Sri Lanka due to its horticultural value. However, two years after its deliberate introduction, a Water Hyacinth Ordinance was enacted in 1907, which indicated the understanding of the long-term detrimental effects of this invasive alien plant by the policy makers of Sri Lanka even more than 90 years ago. However, despite this effort, *E. crassipes* has become 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 the 1980s, but have not performed to the expected levels. Thus, mechanical removal has been practised to clean water bodies infested with this aquatic weed, which in turn has resulted in its further spread due to contamination of the machinery used (Marambe, 1999).

Lantana (*Lantana camara*), a plant introduced for its horticultural value and attraction of butterflies, has been intentionally established in sugarcane-growing areas in the Southern Province of Sri Lanka to protect the cane plants from elephant damage. However, the weed has now invaded lands of one of the major elephant sanctuaries in Sri Lanka at Uda Walawe, significantly reducing the grazing fields of the elephants. The plant is widespread island-wide and commonly found in dense stands along the roadsides and abandoned lands.

Myroxylon balsamum has been introduced to the Central Province of Sri Lanka as a wind break and has now developed into a mono-specific stand covering a large extent of the Udawattekelle Nature Reserve, in Kandy district. Cultivation of *Tithonia diversifolia* in Sri Lanka was encouraged by scientists and academics as a major green manure crop in the early 1980s. However, the plant has now escaped from the cultivated sites and is colonizing roadsides and abandoned lands in most parts of the country. Gorse (*Ulex europaeus*) is confined to the Horton Plains, located in the upcountry region of Sri Lanka, and is changing the habitat of this nature reserve. Although efforts have been taken by many organizations to eradicate this weed, the attempts were aborted because an endemic lizard seeks protection from this thorny plant. Mesquite (*Prosopis juliflora*) is a species introduced to Hambantota district in the Southern Province of Sri Lanka in early 1950s to improve the saline soils and as a ground cover (Algama and Seneviratne, 2000). The species has now become invasive and a serious threat in the Bundala National Park, the only wetland in Sri Lanka listed under the Ramsar Convention.

Deliberate introduction of invasive alien plants through other sources and their spread

Salvinia (*Salvinia molesta*) was introduced to Sri Lanka in late 1930s for scientific interests, but currently has become a major aquatic weed in Sri Lanka, choking the irrigation canals and water bodies, and also invading rice fields in the Northwestern Province. Although there is no accurate recent information on its degree of infestation, in 1988, about 8,000ha of rice fields were reported to have become infested with Salvinia (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. An eradication campaign for Salvinia was initiated in 1957 with community participation but was abandoned in 1964 due to financial difficulties. Although the biological control with *Cyrtobagus salviniae* has been 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 (*Mimosa pigra*) was recently found in Sri Lanka growing luxuriantly on the riverbanks of Mahaweli (a major source of irrigation water that supports the agricultural crops in Sri Lanka), and in other areas in the central province where it is 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 invasive 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 of mature pods from the use of the stems of the plant as firewood by people (Marambe, 2000).

Alligator weed (*Alternanthera philoxeroides*) was an accidental introduction to Sri Lanka, which has spread rapidly due to human intervention. The weed, easily mis-identified as 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 Department of Agriculture has now taken measures to eradicate the plant from cultivated land with the assistance of the farming community.

Congress weed (*Parthenium hysterophorus*) is the latest recorded invasive alien 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 Vavunia district of the northern province. The weed was first believed to have entered the country in the late 1980s through the goats imported from India by the Indian Peace-Keeping Force (IPKF). However, more recent information indicates that the seeds of *P. hysterophorus* may have 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 the spread of alien species.

Leucaena (*Leucaena leucocephala*) was introduced to Sri Lanka as a multipurpose tree species in the early 1980s. Although a psyllid bug infestation destroyed the *Leucaena* cultivation initially, the identification and cultivation of resistant varieties has now enabled the plant to escape from cultivated land and spread at an alarming rate in the southern province. Recently, *Anredera cordifolia*, a perennial vine, has been identified as an invasive weed in tea plantations of Sri Lanka; it may be an intentional introduction to tea plantations as the tubers of this plant are edible (S.L. Ranamukaarachchi, pers. comm.).

Community participation in management of invasive alien species in Sri Lanka

As deliberate or inadvertent human involvement is an important factor in introduction and distribution of invasive alien plants, any management practices of alien plants should also consider the involvement of human beings. Management of invasive aliens can be categorized into several groups: education and awareness; legislation; prevention of introduction; information; and control measures. All require involvement of people.

Having recognized the great threat of invasive plants to the ecosystems, environment and economy of Sri Lanka, the Ministry of Forest and Environment conducted a workshop on invasive alien plants in Sri Lanka in 1999. This national workshop considered all aspects of invasive species and the participants identified and prioritized several species, predominantly plants, as invasive aliens in Sri Lanka and started to develop a working strategy for control of invasive species. However, progress of the development of the action plan is extremely slow.

Apart from a few selected weeds such as *Eichhornia crassipes* and *Salvinia molesta*, Sri Lanka has no policy-level initiative to control IAS. Part of the problem is lack of knowledge on consequences of the presence of invasive aliens on ecosystems.

a. Education and Awareness Programmes

Education and awareness programmes can be conducted at several levels, namely general public, secondary education, University education and farmers. This aspect has been fairly well addressed in Sri Lanka and several media have been used (i.e., TV and radio programmes, popular newspaper articles, video programmes, popular seminars and lectures, etc). Many Sri Lankan universities have included the growing problem of IAS into the their curricula, both at undergraduate and postgraduate levels. It would be very useful to develop guidelines for local and foreign tourists, especially when they visit natural forests, because they should be aware of

the invasive aliens in the country, their potential threat and how humans help to disperse and introduce those invasives into new ecosystems.

Even conservation organizations need to increase their awareness of IAS. For instance, some fast-growing invasive alien plants, such as *Annona glabra* and *Alstonia macrophylla*, are used for tree planting campaigns. On the other hand, unplanned invasive species eradication campaigns have also proven detrimental to native biota. For example, several local NGOs launched a manual eradication programme to remove gorse (*Ulex europaeus*) spreading in the montane zone grasslands. The gorse bushes are inhabited by several species of endemic herpetofauna, as these shrubs provide food (i.e., insects attracted to flowers) and cover. However, when these shrubs were removed haphazardly, the herpetofauna inhabiting them were exposed to opportunistic carnivorous birds in these areas.

b. Legislation

Legislation is essential to avoid spread of invasives and importation of aliens. The existing legal framework for regulating planned and unplanned introduction of alien species is heavily biased towards pests, diseases and weeds and is inadequate to address the impacts on biodiversity. Except for the Water Hyacinth Ordinance, none of the other legislation deals directly with IAS that threaten native biota. This has led to many institutional and some legal disputes in relation to the import of alien organisms. Enforcement of the existing laws is highly inadequate. Two regulatory and enforcement authorities (Department of Wildlife, Department of Customs) which have recognised the importance of prevention of entry of IAS are facing stiff resistance from the private sector which is involved in activities which facilitate such entry. The obvious discrepancies between macroeconomic policies and those on the environment, and between sectoral policies and legislation (i.e., trade and environment), underlie the conflicts and lack of cooperation at the institutional and other operational levels. Although Sri Lanka has a good quarantine regulation (import control legislation, etc.), sometimes its rules are neglected (i.e., recent release of mango and mango plants against the Plant Protection Act). National rules and regulations must be reviewed according to the current conditions.

c. Research

Research on invasive aliens in Sri Lanka has been based mainly on personal interests and in an *ad hoc* manner. Individuals are working based on their interests on various aspects of invasive alien species ranging from pure biology to management and utilization of species on *Mimosa pigra, Myroxylon balsamum, Prosopis juliflora,* etc.

d. Management

Actual management of invasive alien species is rare in Sri Lanka. The results of the few examples mentioned above suggest that control and eradication is not an easy task, and will require long-term well-planned experiments to understand ecological interactions of aliens with the natural ecosystems.

e. Policy

Focus on the larger picture of impacts of IAS on the environment is lacking. The virtual absence of detailed economic, social and political aspects of IAS has led to a void in policy advocacy based on sound technical information. Overall, the lack of awareness within the country, ranging from policy and decision makers to the local resource users, of the nature,

modes of entry and establishment and interventions required to reduce the negative impacts of IAS are highly detrimental to attempts to preserve native biodiversity for the long term.

Conclusions and recommendations

Sri Lanka urgently needs an effective mechanism to deal with all activities related to IAS. Ministry of Forestry and Environment of Sri Lanka, the national focal point for the CBD, would be the ideal coordinator of such initiatives. Education and awareness are the key elements to remedy the threats of the invasive species to natural agricultural ecosystems of Sri Lanka. There is an urgent need to improve current and future management programmes of IAS by using historical and existing measures more strategically and effectively, and integrating the efforts of all stakeholders, including governments at all levels, non-governmental organizations, industry, community groups and the general public. Thus, a national invasive species action plan is required, prepared and implemented through a coordinating body which oversees all aspects of issues of IAS, including the human dimensions.

The Special Role of Horticulture

The human dimensions of invasive woody plants

Pierre Binggeli

Abstract

This review of the human dimensions of invasive woody plants investigates the history and purposes of introductions, people's perceptions of alien and invasive species and the impact of invasives on human activities. A perusal of the literature indicates that all aspects of the human dimensions of alien woody plants are highly varied and some are still poorly documented. Changes in the usage of species over time as well as conflicts of interest in relation to species introduction and biological control show that alien woody plants cause social and economic problems and conflicts related to human activities. These problems interact with a variety of human activities and these issues need to be addressed with care.

Introduced woody plants

Woody plants have undoubtedly been transported by humans for millennia and were an essential component of early agricultural societies. Indeed, many regions of the world, and oceanic islands in particular, would not have been colonised without the introduction of various crops, many of which were woody plants. In these early societies woody plants were a source of a wide array of basic materials as well as food. In more recent centuries the type of species translocated has shifted with an ever-increasing proportion being ornamental plants.

Over the past two centuries many species have started to spread in their introduced ranges. Until relatively recently the majority of introduced woody species have been highly beneficial, if not essential, to humanity's development, but now ever-increasing numbers of species are becoming detrimental to the maintenance of the earth's biodiversity and to the well-being of human societies. This chapter attempts to unravel the relationships between humans and woody plants by looking at the changes in the introduction of species, the way they are perceived by different human groups and the impact these invasive species have on human activities. Finally, key examples illustrate how socio-economic factors and species utilisation may vary through time and that conflicts of interest between different groups often are inevitable.

Historical perspective of plant introductions

The history of woody plant introduction is closely linked with that of transportation and the European exploration of the planet (16th–19th century) (Crosby, 1986). At various times in European history some individuals greatly enhanced the discovery and introduction of new species. For instance, in Britain Joseph Banks was instrumental in the setting up of Kew Gardens as a major centre for economic plants and in promoting plant prospecting (O'Brian,

1987). Each colonial power established major botanical gardens and experimental stations in various parts of the world, first in the home country and on tropical islands, later in coastal areas and finally in more inland locations.

By the 20th century, the purpose of introductions shifted from food plants to timber and other species yielding non-agricultural products. Finally, during the latter part of the 20th century the importance of ornamental species increased dramatically, especially to the more developed and wealthier regions.

The timing and nature of species introduced vary in various parts of the world, as illustrated by tropical Africa and the Pacific islands. In tropical Africa four main phases of woody plant introductions may be recognised (Binggeli *et al*., 1998):

- Early exploration and slave trade during which time a few fruit tree species were planted at a number of coastal locations.
- Early colonial period when at the end of the 19th century a number of experimental gardens were established by missions and private individuals. These were followed by several major botanic gardens established by the respective colonial powers in the 1890s. These gardens specialised in testing economic exotic plants but ornamentals were also introduced.
- Colonial exploitation, when large-scale forestry plantations were established after World War II using a number of introduced timber tree species.
- Post-colonial development with an increase in the number of species and provenances as well as the number of planting locations.

In the Pacific, Polynesians introduced many economic woody plants prior to European colonisation (Bevacqua, 1994; Barrau, 1967). Throughout the European exploration of the Pacific, seeds of economically valuable species were introduced to visited islands and expeditions were even mounted to collect valuable food plants such as the breadfruit, *Artocarpus altilis* (O'Brian, 1987). Even captains of navy ships would introduce seeds of edible species and instruct indigenous people how to grow them (Porter, 1986). In the 19th century economic gardens were established at a few locations (e.g., New Caledonia, Gargominy *et al*., 1996) and in the 20th century botanic gardens with the purpose of establishing exotic ornamental plants were established (e.g., Tahiti, Meyer, 1994).

Purpose of introductions of woody plants

With the exception of a very few species, such as *Clidemia hirta* in Madagascar (Cabanis *et al*., 1970), primary introductions of woody plants have been intentional. That is, the transport of a species from one biogeographical region to another was carried out with a particular purpose and these are reviewed below. Once introduced to a new region, many of these species have been spread un-intentionally by humans within the new biotic regions. These secondary introductions are chiefly of species with small seeds (e.g., *Miconia calvescens*) accidentally transported by vehicles or soil, or clonal species (e.g., *Fallopia japonica*) moved with soil material. These instances will not be discussed here.

The purpose of introduction of species which have become invasive is in decreasing order of importance: amenity (about half of the reported cases); forestry; agriculture; landscape; and botanic gardens (see Binggeli, 1996 and Binggeli *et al*., 1998 for details). This section aims to illustrate the diversity of purposes involved in species introductions.

Agriculture

Especially during the discovery and conquest of the world by western European powers, fruit trees were widely dispersed around the globe. Many species were introduced as foodstuff for

livestock, for example *Prosopis* spp. to Kenya (Anon., 1997a) with both foliage and fruit being edible. In the USA *Lonicera japonica* provides emergency winter grazing for cattle (Blaisdell, 1967). The introduction of *Chromolaena odorata* to West Africa was recommended to control weedy grasses, particularly *Imperata* spp. (Chevalier, 1952). It is alleged that a planter introduced the weedy *Rubus mollucanus*, called 'vigne marrone' (wild vine), from Réunion to Madagascar because he mistook it for the grape vine (Koechlin *et al*., 1974).

Forestry

Throughout the 20th century the large-scale planting of trees for timber production has been one of the main reasons for the introductions of a large number of species, especially conifers (e.g. *Pinus* and *Picea* species) and eucalypts, throughout the temperate and tropical regions (for details see Richardson, 1998). Introductions of woody species for fuelwood production, such as *Prosopis* spp., has been common in developing countries (e.g. Kenya, Anon., 1997a; India, Gold, 1999).

Environmental

Erosion control has been a common reason for the introduction of plant species in many parts of the world. This practice was very widespread in the USA and species like *Cytisus scoparius* (Blaisdell, 1967) and *Pueraria lobata* (Koopowitz and Kaye, 1990) were widely planted by government departments such as the Civilian Conservation Corps. Species providing a rapid and thorough cover such as *Lonicera japonica* and *Pueraria lobata* have been favoured but these have become major pests (Williams, 1994). In Hawaii *Rhizophora mangle* was introduced to stabilise coastal mudflats (Allen, 1998). *Elaeagnus angustifolia* was commonly planted as a windbreak and *Lonicera japonica* was planted by game managers for wild deer (Blaisdell, 1967). In countries such as Britain shrub species such as *Symphoricarpos albus*, were introduced to provide ground cover for game birds (Gilbert, 1995).

Amenity and botanic gardens

Ornamentals have been widely introduced in every part of the world. In the past, botanic gardens and individuals were responsible for these introductions. In 1833 the English botanist R.T. Lowe introduced *Solanum mauritianum* to Madeira and this species is now widely naturalised (Press and Short, 1994). *Lantana camara* was introduced to Sri Lanka at the request of the wife of the British consul who had been positively impressed by the plant when she visited Brazil (Guenther, 1931). Botanic gardens in all parts of the world have been responsible for the introduction of a large number of species and in every case species have started to spread into the surrounding vegetation (e.g. *Acacia dealbata* in southern France, Gams, 1967; *Lantana camara* in New Caledonia, Gargominy *et al*., 1996). Directors of some of these botanic gardens, which were originally chiefly concerned with the introduction of economic plants, were keen collectors of exotic ornamentals (Binggeli *et al*., 1998; Gargominy *et al*., 1996).

Scientific

Scientists themselves may sometimes be responsible for species invasions. For example, a field scientific experiment set up to investigate salt excretion of various plants at Mission Bay (California) in the late 1960s resulted in a thriving population of the small tree *Avicennia marina* a decade later (Moran, 1980).

Although the French botanist Auguste Chevalier regarded *Chromolaena odorata* as a weed (Chevalier, 1949) and had written a paper on man's role in the dispersal of tropical plants (Chevalier, 1931), he nevertheless recommended its introduction to West Africa to control weedy grasses (Chevalier, 1952).

Some scientists consider that the introduction of threatened plants from one oceanic island to another is a tool of conservation worth considering only with the greatest caution (Waldren *et al*., 1995).

Warfare

Woody plants were introduced and planted to camouflage military installations in many parts of the Pacific during World War II. The Japanese planted *Leucaena leucocephala* to hide fortresses on the Ogasawara (Bonin) Islands (Pacific) and the American military used *Ulex europaeus* on the Puget Sound to protect gun placements from attacks. Both species have since spread (Paterson, 2000). In earlier times, navies of various maritime nations introduced many plants and animals to remote islands as future food sources. During the war between the USA and Britain, for example, Captain David Porter (1986) of the US Frigate Essex reported that in 1813 he was planting seeds of a variety of plants, including citrus fruits, in native villages of the Madison's Island (Pacific).

The Dalaba Garden in the former French Guinea was initiated in 1908 with around 950 species being planted and a nursery was also established in 1914 with forest tree species originating from Indochina. When the two Europeans in charge were mobilised at the onset of First World War both the gardens and the tree nursery were abandoned and by 1947 the former had disappeared whereas the latter consisted in a small forest. The structure and species composition of this stand was similar to a south-east Asian forest and many of the species were reported to be regenerating in the undergrowth (Chevalier, 1947).

Traditional uses

Little is known about the introduction of woody plants for traditional uses, such as medicinal and religious practices. Under-reporting is likely to be a cause for the dearth of information. *Protasparagus* sp. is said to have come to Norfolk Island in the 1930s in a bridal bouquet (Macrae, n.d.). Shaw (1994) has reported that *Abrus precatorius*, a non-invasive leguminous climber from India, was introduced to Britain by the Asian community. Although its seeds may cause death when eaten, they are traditionally used as a potent contraceptive. *Sorbus aucuparia* is valued, particularly in Ireland and the highlands and islands of Scotland, for its protective powers (Vickery, 1995) and it is likely that this small tree was introduced to New Zealand and North America, where it is spreading, for its magical powers rather than its ornamental value. The seeds of *Albizia lebbeck*, introduced from Asia via Mauritius in 1814, are widely used in divination (Sikidy) in western Madagascar (Morat, 1972).

People's perception of exotic and invasive woody plant species

From a perusal of the scientific literature it would appear that issues relating to invasive woody plants are chiefly, and sometimes only, the concern of scientists and conservationists. In this section a number of examples are given to illustrate the importance of invasive woody plants to indigenous people and also to document how these populations view the problem. Cultural and political aspects of non-native species and their effect on people's perception of invasive species, including that of scientists, are also addressed.

Plant names

Local names of introduced woody plants are varied and are often imported with the plant. However, in many instances the plants are named after the person who first introduced them. For instance, *Cordia sebestena* is commonly called the Geiger-tree after John Geiger, an early

19th century ship pilot, who first planted this tree at Key West in Florida (Little, 1979). Other names reflect a fact relating to the introduction, such as the chicken tree (*Sapium sebiferum*) which used to be commonly planted around chicken coops in Louisiana, USA (Jubinsky and Anderson, 1996).

Woody species which have become serious weeds have been given names which clearly reflect their pest status and also often point at the name of the person responsible for the introduction of the plant (Table 1).

Table 1 Examples of common names of woody plants referring to their weediness.

Common name	Scientific name	Region	Source
Burbank's folly	*Rubus discolor*	Pacific Northwest	M. Edain (pers. comm. 2000)
Koster's curse	*Clidemia hirta*	Fiji	Paine (1934)
Ellington's curse	*Acacia farnesiana*	Fiji	Howes (1946)
McConnel's curse	*Gleditsia triacanthos*	Australia	Anon. (1997b)
Curse of India	*Lantana camara*	East Africa	Pratt and Gwynne (1977)
L'envahisseur	*Chromolaena odorata*	Cameroon	Baxter (1995)
Devil's fig	*Solanum torvum*	Papua New Guinea	Chadhokar (1976)
Fiente de sauterelle or Kondogbo	*Solanum verbascifolium*	Sierra Leone	Portères (1959)

Rajasthan

In Rajasthan *Prosopis juliflora* is called 'vilayati bambul' and often simply referred to as 'vilayati', 'foreign' while the native *Acacia nilotica* is known as 'desi bambul'. It is said that to unpractised eyes they look very much alike, but the latter species often fails to regenerate while the former has become a weed. Gold (1999) has investigated the cultural history of a rural village community faced with environmental change in an arid part of the Indian sub-continent. The region has suffered from massive deforestation and *P. juliflora* has become the only source of fuelwood for the local population. The older generations remember clearly what their environment used to be like, while young people are not fully aware of the changes that have taken place.

Local people's perception of *P. juliflora* is that the species has averted a serious fuel shortage but has been accompanied by several negative effects:

- it colonises agricultural land and is hard to remove;
- its thorns cause dangerous infections;
- the thorns play havoc with bicycle tires;
- the leaves are unappealing to goats;
- in its shade no grass or crops will grow.

Children as well as adults can evaluate the merits of *P. juliflora* compared to that of native trees and the changes that have occurred. Much of the area used to be covered with native trees which local people believe used to increase rain, whereas now *P. juliflora* is dominant. Much of the hills used to be covered by *Anogeissus pendula*, an excellent firewood, and this species was thornless. Village people often contrast *A. nilotica* with its multiple uses to *P. juliflora* which is only good 'for burning'. They know that goats eat the seed pods and new trees sprout from their dung, thus the species needs no human assistance, whereas most species of native trees must be protected from livestock and watered for several years. Locals believe that trees have souls but people need to cut trees to survive; however it is not a sin to cut *P. juliflora*. A young girl was

reported as saying that it is not a sin to kill a poisonous animal (e.g. snakes) and that the same applies to the foreign tree.

At first *P. juliflora* was found around a nearby town and later started to spread out, and then it was extensively planted by the Forest Department. At the time of its introduction the tree was welcomed as a field boundary. However, people rapidly became aware that the species had fewer positive assets when compared to native species and they have associated the "foreign" tree with a reduced quality of life. Yet in 1993 a Japanese-funded aid programme to improve India's environment was established in the village to propagate and plant over 20,000 *P. juliflora* on the hilly wastelands. Gold reported that no one opposed the project and that the school ran the tree nursery and the planting work was cheerfully carried out by local women.

Polynesia

Over the past two centuries the people of the small and remote island of Pitcairn (South Pacific) have struggled to scratch out a living despite isolation and environmental unpredictability. In order to improve their chances of survival, all new plant species which would either enhance their agriculture or provide ornamental flowers lacking on their island, have traditionally been welcomed to the island. In the process they have introduced many plants, pests and diseases. Many individuals have been fully aware of the problem and the Pitcairn situation has been vividly depicted in 1962 by Roy Clark, one of the island's long-term residents. Incidentally, Clark's perception of the invasive problem was far more accurate than that of the scientists who visited in the early 1990s (Binggeli, in press). Despite this awareness that introductions, without screening and proper quarantine, will lead to the spread of undesirable aliens, the local people have failed to curb their traditional inordinate fondness for introducing new plant species to the island.

Their perception of the status of introduced species is different from that of conservationists. In recent years Pitcairners have not considered *Lantana camara* as a major weed, as conservationists have done, but believed the shrub to be a soil improver. On the other hand the tree *Syzygium jambos* is viewed as a major pest, not because of its impact on the native flora and fauna, but rather because of its heavy shading and its spreading, shallow and dense rooting system which renders cultivation of gardens an arduous task. The weed status of a species relates to the way it interferes with day to day activities and will change through time as society develops (Binggeli, in press).

Probably due to the lack of 'photogenic' flowering plants two series of Pitcairn stamps produced by the Island's administration, based in New Zealand, have prominently featured the island's key invasive plants.

The recent *Miconia calvescens* invasion of the Pacific island of Tahiti (French Polynesia) has been rapid and dramatic and has received considerable attention from scientists, conservationists and the media. The public has been given much information relating to this major weed which affects mainly the ecological integrity of the island rather than people's day to day activities. Statements in Table 2 show that the population's understanding and views of the problem are highly varied. Tahitians using the countryside are clearly aware of the impact of the tree whereas others are poorly informed despite widespread publicity campaigns carried out by local authorities. These media efforts have included newspaper articles, TV programmes and a poster campaign entitled "Miconia, le Cancer Vert" (Miconia, green cancer).

Table 2 Views about and perception of *Miconia* by Tahitians (J.-Y. Meyer, pers. comm., 2000).

Informant	*Comment*
Teenager	"I thought it was a native plant, I have always seen it everywhere"
Horticulturist	"what a nice plant"
Old person	"all the fe'i [*Musa troglodytarum*] have disappeared in this valley since the arrival of *Miconia* in the 1970s"
Pig-hunter	"what a pest"
Middle-aged woman	Thought the small tree was a vine until she saw it on TV
Middle-aged man	Refused to carry a potted *Miconia* because he didn't want to catch some bad disease after noticing the poster entitled "Miconia, le Cancer Vert"

On the distant and rarely visited Island of Rapa the introduced *Rubus rosifolius* was first collected in 1926 (Meyer, 1998). In 1947 it was reported that "The Rapans think they are a prickly nuisance" (Johnson and Johnson, 1956).

Media

In recent years invasive woody plants have gained much coverage in the media. Many articles have been published in newspapers and magazines. In view of the problem caused by biological invasions, this is welcomed, although sometimes the way the subject is reported may be cause for some concern. Newspaper and magazine publishing is becoming increasingly competitive and the trend is to promote stories with a high profile and especially those that are highly controversial. Stories about aliens obviously fit the requirements of modern media (see Table 3 for examples) but there is a danger that the message sent out to the public misrepresents the problem at hand.

Table 3 Striking article titles in newspapers and popular magazines.

Newspapers
I think that I shall never see a thing as deadly as a tree (Villano, 1988)
Popular magazines
The on-going battle against aliens (Anon., 1983)
South Africa's other bush war (de Selincourt, 1992)
Creeping invasion of the "green cancers" (Wicht, 1971)

In Britain the public view of *Rhododendron ponticum* invasion and control is influenced by how the media portrays and interprets the situation. Despite being provided with briefings and literature by the Snowdonia National Park, newspapers often publish articles that misinform the public (Gritten, 1987) and the debate is commonly muddled up by the transfer of anthropomorphic concepts to plants (Binggeli, 1994a).

Foresters and horticulturists

Foresters only view an introduced woody plant as a weed when it starts interfering with silvicultural operations, especially when access by machinery and personnel becomes more difficult or when young plantations are suppressed. In Britain some foresters view *Rhododendron ponticum* as weeds while others do not. The species is not considered to be a major problem in plantation forestry although afforestation will not be carried out on areas infested by *R. ponticum* (Gritten, 1987) whereas it is viewed as a serious problem in the management of native woodlands (Tabbush and Williamson, 1987). In Northern Ireland the shrub *Rubus spectabilis* is now spreading into some conifer plantations and is considered to be a problem by the local foresters. Yet other foresters in Northern Ireland are not aware of the potential problem and when told about it they tend to dismiss it as a localised issue.

Different countries have very different approaches and views on exotic woody plants. The contrast among foresters and horticulturists between Britain and Germany is striking. In Germany the great majority of foresters are aware of the invasive problem whereas only 40% of managers of urban green areas are aware of this issue (Kowarik and Schepker, 1998). Indeed German foresters will not use exotic species and are very particular in their choice of provenances (Binggeli and Rushton, 1999) whereas landscapers will favour non-native species and provenances. Some academics have even suggested that the bias in favour of native species and against aliens is a continuation of Nazi policies (Groening and Wolschuke-Bulmahn, 1992). In Britain the converse is true, especially among foresters, who basically seem to have no interest in native species.

Conservationists

It is well known that conservationists dislike or even hate introduced woody plants. There are, however, a few instances where an invasive woody plant, if it can be kept well under control, becomes a positive asset. In Ireland the shrub *Hippophae rhamnoides* forms monotypic stands on coastal dune systems. A belt of this impenetrable thicket is kept and regularly contained between a nature reserve and a caravan park. This prevents various types of unwelcome holiday-makers (e.g. yobs, lager louts, and frolicking couples) from entering and damaging the reserve (D. Riley, pers. comm.).

Scientists

Although the interest in invasive species stems back to the mid-19th century (de Candolle, 1855), scientists generally neglected the issue until the 1980s. Differences in scientific traditions relating to the perception of vegetation as well as scientific methods have meant that greater emphasis has been placed on invasive woody plants in Anglo-Saxon countries than elsewhere. In the 1950s "ecologists worked mainly in natural systems, often avoiding human-modified systems and alien organisms as if these were 'noise'" (Richardson, 2000) and many phytosociologists have maintained this tradition much longer. Indeed in Brazil, despite a large number of invasive plants, scientists have no interest in plant invasions (S. Ziller, pers. comm., 2000). In Madagascar, throughout most of the 20th century, invasive species were only viewed as a problem if they were deemed to be harmful to human activities but especially if they were economically detrimental (Perrier de la Bathie, 1928).

Even when plant scientists have investigated invasives they have often failed to perceive the problem properly. In relation to the time-lag between the introduction, the spread and the pest status of an introduced woody plant, the reasons behind the failures and successes in detecting and understanding these time-lags have recently been identified (Binggeli, in press) as follows:

Failures:

- poor natural history skills and inability to understand species autecology in relation to ecosystem dynamics;
- lack of historical research and of the 'grey' literature in particular;
- poor use of local knowledge. Either this knowledge is not used or scientists misunderstand what locals are saying.

Successes:

- good knowledge of the ecosystem and of the flora in particular;
- regular monitoring;
- good historical records;
- learning from experiences in other regions;
- chance.

Western societies

More materially developed societies have had many more opportunities to introduce alien woody plants and more time to ponder about them. This is in sharp contrast with developing countries where day-to-day survival often is the sole concern of a large proportion of the population. The populations of developed countries are highly fragmented into a large array of traditions, opinions, beliefs and political views so that this section can only provide a glimpse of the broad spectrum of perceptions and views relating to invasive woody plants found in the 'Western world'.

In western Europe alien species which were introduced several centuries ago and which have become widespread have amassed a substantial amount of plant-lore. In Britain and Ireland *Acer pseudoplatanus* has been linked with many customs including the traditional May Day festival and in Scotland it became the favoured tree for hangings (Binggeli, 1993).

Much of the western world has become totally ignorant of natural history and the lack of public awareness of plant invasion has been documented (Colton and Alpert, 1998). One of the consequences of this ignorance is reflected in the inability to differentiate between native and alien species. For example, in Poland the 2 Grosze coin depicts the foliage of the American *Quercus rubra* instead of native oak.

Nowhere else than Britain is the mix between politics, ethics and culture so striking and this results in an array of contrasting and often highly controversial views (e.g. Moore, 1992 and Evans, 1996). Any word, action or view regarding introduced species becomes rapidly heavily loaded (Binggeli, 1994a) and renders rational discussions about biological invasions nearly impossible and more importantly prevents action to control invasives.

Adventurers and travellers

When reliable and based on good field observations, accounts by adventurers and travellers bring to light some interesting snippets of information. The Johnsons sailed around the world several times and occasionally made short, but precise, comments about invasives in their publications. For instance in 1947 they reported "the change in the island growth since a blight had killed orange and lemon trees and guavas had spread like wildfire" on the Galapagos Island of Floreana (Johnson and Johnson, 1956).

Sometimes major omissions occur. In 1987 during a Pacific trip the natural historian Andrew Mitchell spent some time on the island of Moorea and extensively reported the problems associated with the invasive African snail (Mitchell, 1989). Yet he failed to notice the invasive and highly conspicuous tree *Miconia calvescens* which by the early 1990s was recorded as covering substantial areas of the island (Meyer, 1994).

Impact of invasive woody plants on human activities

This section reviews the impact of introduced and invasive woody plants on human activities. This review is not exhaustive but is intended to demonstrate the broad spectrum of human activities that may become affected positively or negatively by non-indigenous species. In general, the majority of introduced species which have become invasive have been reported to have both positive and negative impacts on human activities, but from the reported impacts on human activities it would appear that the majority of invasive species exhibit more deleterious than positive impacts. Unless otherwise stated, all information is based on species accounts found in Binggeli *et al*. (1998).

Agriculture

In many parts of the world, but especially the tropics, grasslands are invaded by introduced woody plants and reduce the livestock carrying capacity of these pastures and sometimes make livestock farming uneconomic in places (e.g. *Acacia nilotica* and *Mimosa pigra* in northern Australia, *Psidium guajava* in Fiji and *Ulex europaeus* in many temperate and tropical regions). Some, like *Lantana camara*, are also poisonous, resulting in the death of cattle and sheep. Horses lose their hair when feeding on *Leucaena leucocephala* as both foliage and edible seeds contain the amino acid mimosine which is toxic in large quantities. Toxicity and even death in livestock has been reported in Kenya from pods of *Prosopis* spp. (Anon., 1997a).

Tree locust (*Anacridium melanorhodon arabafrum*), a major pest in Africa, and hitherto not a problem in the region of Lake Turkana (Kenya), was found to be feeding on *Prosopis* spp. These trees were introduced in the early 1980s and within a decade have covered large parts of the region and thus have given a chance to this potentially devastating pest to become established in the area (Anon., 1997a).

A number of widespread species are weeds in agricultural lands (e.g. *Chromolaena odorata*, *L. camara* and in Fiji *Clidemia hirta*). In the Marquesas Islands farmers consider *Leucaena leucocephala* as an agricultural weed which is nearly impossible to uproot completely. Similarly on Pitcairn Island the dense and extensive root mat produced by mature *Syzygium jambos* trees is detrimental to shifting agriculture or in agroforestry systems. Species such as *Clidemia hirta* may also hamper the development of plantations (cocoa, rubber).

In northern Australia *Mimosa pigra* has a detrimental effect on fishing as it restricts access to waterways to fishermen.

Many invasive species have some economic value as a food source. In India, thickets of *Prosopis juliflora* harbour many bee hives and nearby villagers extract the honey (Sharma, 1981). Species such as *Melaleuca quinquenervia* in Florida and *Syzygium jambos* appear to be important sources of nectar and pollen to the beekeeping industry. In the case of *M. quinquenervia*, its nectar and pollen are important for maintenance and the build-up of colonies, however its flavour is unpleasant and if present in a proportion higher than 5% in *Citrus* honey it makes the latter unsalable (Morton, 1964; Robinson, 1981). Species infested with aphids produce large quantities of honeydew which is readily gathered by bees often resulting in honeys with unpleasant flavours (Morton, 1964). *Acer pseudoplatanus* flowers when there is a dearth of ripe flowers in the British countryside and has therefore been ranked among the 13 most important pollen sources for bees (Howes, 1945). Many other invasive species are also visited by bees and they are claimed to be of value to bee-keepers but their importance has yet to be demonstrated. Some species are clearly unsafe sources of nectar or pollen as they may kill the bees or the resulting honey may be more or less toxic to humans as in the case of *Nerium oleander* (Morton, 1964). The fruit of *Passiflora mollissima* is widely grown and sold in New Zealand, but it has no economic value in the tropics. The fruit of *Psidium guajava* is highly valued yet in many regions the shrub is considered a pest.

Forestry

Numerous shrubs and woody vines interfere with forestry operations, especially with plantations. In New Zealand the vine *Passiflora mollissima* is a major problem, particularly following logging, and the shrub *Buddleja davidii* may outcompete newly-planted conifers. In the tropics both *Lantana camara* and *Chromolaena odorata* may be a problem and the former may even over-run young plantations. Tree health surveys in Northern Irish woodlands where the undergrowth is dominated by dense stands of invasive shrubs may take three times as long to carry out than on uninfested sites. The undergrowth hinders access to tree trunks as well as obstructs the view of their canopies, both of which need to be visually examined for fungal attacks (P. Blackstock, pers. comm., 2000).

Access to older plantations and natural forests may be seriously hindered in both the temperate (e.g. *Rhododendron ponticum* in Britain and Ireland) and tropical zones (*Lantana camara*). In Indian sandalwood forests *Lantana camara* not only competes with the tree crop but also favours the spread of the sandal spike disease.

The timber and wood value of invasive trees varies tremendously. In Malawi the timber of *Pinus patula* is worth only 5% of the native *Widdringtonia cupressoides*, which it is displacing. In Jamaica, the Australian *Pittosporum undulatum* is preferred by locals for firewood and may have potential as a source of timber. In many regions *Psidium guajava*, a neotropical species invading most of the tropics, supplies valuable firewood. In parts of the Indian Thar Desert the central American *Prosopis juliflora* may supply up to 90% of the villagers' fuelwood requirements as well as much of their needs in construction wood (Sharma, 1981).

Natural regeneration of desirable IAS is often viewed as positive by foresters. Alternatively natural regeneration of an exotic tree may be used to produce timber whenever control attempts have failed. In the northern French forest of Compiègne *Prunus serotina*, a North American tree introduced as game cover, has been steadily spreading in logged areas. Having failed to suppress the species, local foresters have decided not to combat it anymore. Now, they try to produce a harvestable crop as sawmillers do not differentiate between the timbers *P. serotina* and the native *P. avium* (Décant, pers. comm., 2000).

Leisure activities

In many parts of the world invasive woody plants tend to form monotypic stands which typically make the countryside less accessible to the public. Some species simply form dense stands which are difficult to walk through (e.g. *Casuarina equisetifolia*) but many are covered with sharp spines and render access impossible (e.g. thorny varieties of *Lantana camara*, *Rubus* spp.). *Ulex europaeus* even produces a persistent spiny litter. In northern Australia *Mimosa pigra* restricts access to waterways. A few tree species (*Syzygium jambos*) have the opposite effect as they suppress both the ground vegetation and shrub layer, thus favour access by humans.

Species forming monotypic stands will also seriously alter the physiognomy of the landscape. However the impact will vary depending on the values and judgements held by the observer as well as his/her perception of nature. A shift from grassland to woody vegetation, for example, readily diminishes the view. Similarly the spread of a shrub in forested landscapes (e.g., monotypic shrub layer of *Rubus spectabilis* in Irish broadleaf forests) dramatically alters the view experienced by visitors. The spread of *Acacia nilotica*, native to the Indian peninsula and much of Africa, may have an impact on the number of tourists frequenting the Baluran National Park (Java, Indonesia) as most visit the park to view large herds of herbivores in open grasslands. On the Cape sand plain of South Africa the alien acacias, unlike the low native fynbos vegetation, obscure the punters' view of racecourses (McDowell *et al*., 1991).

More subtle effects are produced by differences in foliage shape and size as well as colour and this is clearly illustrated by *Miconia calvescens* in the Pacific. At the time of flowering,

Rhododendron ponticum is perceived as a key landscape feature of Wales by a large proportion of the British public.

Urban areas

Introduced trees may cause a greater physical hazard to the public and property than native species. In Florida *Casuarina equisetifolia* is considered as a public safety hazard. During hurricanes the fall of this tall tree (up to 30m) can damage property or block evacuation roads. In northern areas frost-killed trees become a nuisance due to the fall of branches and crowns. In Hawaii the shrub *Clidemia hirta* grows densely along roadsides, thus increasing maintenance costs of verges.

Unwanted regeneration and vegetative spread is a serious problem in many urban and suburban areas throughout the world. Some trees become established on buildings making them unsound. Other species become established along roadways and pavements or spread vegetatively, damaging road surfaces (e.g. *Ailanthus altissima,* Newton, 1986). Elsewhere seedlings of introduced species become established in public areas and private gardens (e.g. *Acer pseudoplatanus* in Britain and *Schinus terebinthifolius* in Florida) which is unwelcome and increases maintenance costs. When establishment occurs along property boundaries in sub-urban areas this sometimes results in serious disputes. An extreme example from Britain illustrates the potential problem. The non-native, but non-invasive, Leylandii (x *Cupressocyparis leylandii*) is widely planted as a hedge along property boundaries. When uncut the plants rapidly grow into tall trees resulting in boundary disputes, house subsidence and in many instances court cases. These disputes have resulted in much unhappiness, bankruptcies and even murder, and legislation is to be passed to allow local authorities to forcibly cut down the offending trees (Brown, 2000).

Much of the British public object to the tree *Acer pseudoplatanus* in urban areas because it produces much sticky honeydew which coats cars and park benches alike (Binggeli, 1994b).

Health, well-being and traditional medicine

A number of invasive species may be considered as a health hazard. In both temperate and tropical regions large quantities of air-borne pollen of *Ligustrum* spp. (Mowatt and Smith, 1983) and *Casuarina equisetifolia* cause respiratory irritations. In the close vicinity of habitations, both *Schinus terebinthifolius* and *Melaleuca quinquenervia* appear to cause respiratory difficulties in many people (Morton, 1969). Skin contact with leaves and the milky sap of *S. terebinthifolius* results in red, itching rashes.

Children are known to have died after eating unripe berries of the ubiquitous tropical shrub *Lantana camara*. Pods of two *Prosopis* spp. introduced to Kenya were found to be a tasty food by local Turkana people soon after the species started to spread. However, “the pods recently appear to have turned poisonous” and serious stomach problems have been reported (Anon., 1997a).

In Tanzania *L. camara* can be considered as a serious health threat, as its thickets provide breeding grounds for Tsetse flies infected with trypanosomes of domestic animals. *Psidium guajava* provides an excellent breeding ground for insect pests, whilst *Melaleuca quinquenervia* seems to repel mosquitoes.

In many parts of the tropics invasive species are rapidly taken up by traditional doctors and administered as medicinal plants (e.g. in Tanzania, Ruffo *et al*., 1989; West Africa, Burkill, 1985-97). However, the efficacy of these remedies is unknown.

Natural resources and processes

The spread of invasive species, especially those forming monotypic stands, may have important impact on resources essential to local communities (e.g. water, soil erosion) and natural processes which may endanger life and property (e.g. fire, flood).

Ulex europaeus invades watersheds which supply a substantial amount of drinking water. In South Africa it has been estimated that the water used by invasive trees resulted in a 7% reduction in the mean annual runoff, but locally this figure may be as high as 75% and the water-use of invading plants is more than twice that of commercial forestry (Versveld *et al*., 1998).

Some species increase fire risk. In New Caledonia the climbing stems of *Lantana camara* dry out following reproduction and the dead material falls to the ground, increasing fire susceptibility. The shrub *Ulex europaeus* represents a fire hazard to private property in some tropical areas. On the other hand *Ligustrum* spp. appear to have a low flammability (Mowatt and Smith, 1983).

In some mountainous areas (Tanzania, India, Mauritius) the presence of *L. camara* and *Rubus* spp. was once considered as a good erosion-preventing ground cover (e.g. Strahm, 1993).

It has been estimated that in southern Africa the production of fuelwood and charcoal using invasive stands of *Acacia cyclops* and *A. saligna* was worth several million US$ and provided a source of income to probably hundreds of thousands of rural families (Azorin, 1992).

Employment and welfare

In many parts of the world people have gained employment to investigate, manage and control invasive species. In the latter part of the 1990s over 20,000 South Africans have been employed by the Working for Water Programme which has not only given work to poor and disabled people but has also enhanced workers' skills and provided health advice to rural populations (Anon., 2000).

Temporal changes in socio-economic factors and species utilisation

The North American tree *Robinia pseudoacacia* has been widely introduced throughout Europe as a source of high quality timber and for erosion control. Some now regard it as a permanent member of the flora (Gams, 1967). The main uses of *R. pseudoacacia* have been somewhat variable in different parts of Europe and have changed over time. In parts of France and Switzerland the young coppice wood was extensively used in vineyards to support the vines (Monnier, 1992) but in recent decades it has been replaced by metal posts and wire, and now the species is hardly used. Although the tree produces a highly durable timber, it is disliked by German foresters because the wrong strain, a shrubby variety, was introduced to that country. In Hungary the tree has remained a key timber and is the main source of honey (Keresztesi, 1977). Even new uses for the groves of this species have recently been found. The Hungarian Formula 1 Grand Prix brings over 100,000 spectators once a year but also attracts hundreds of prostitutes whose trade, over the past few years, has disturbed the tranquillity of local villages. This has now been restored as the local *R. pseudoacacia* groves have been put to new uses (Thorpe, 2000).

On Pitcairn Island the fuelwood tree *Syzygium jambos* is now widely considered a problem. The main reasons for the spread of this species have been marked changes in the island's population and economy since World War II. The population has steadily declined (drop from around 150 to less than 50 inhabitants) and the source of heat for cooking has shifted from wood

to electricity. As a result much less wood is now harvested and the species has been able to spread.

Numerous species of exotic woody plants have been and still are introduced as ornamentals. The criteria for selection are often very narrow and may include just the ease of propagation and the speed of growth. Potential negative impacts are not considered before the plant is promoted. For instance in Florida *Bischofia javanica* was promoted in the 1910s but soon after its introduction it was discovered to be unsuitable as an ornamental because it grew too big, had large surface roots, its foliage was prone to diseases and it regenerated freely (Morton, 1984). It was also pointed out that it was difficult to kill, yet the tree was widely sold for decades before being rejected. Morton noted that *B. javanica*, with its lack of quality and suitability, was just a typical example of many mistaken introductions to Florida by the nursery and landscaping trade which were detrimental to property owners, the community and the environment.

Conflicts of interest

The value of an alien species may be different to different interest groups and conflicts of interest may arise and sometimes may affect human activities. These conflicts are particularly acute when the introduction of a species is proposed or when a biological control of an invader is considered.

For example, *Chromolaena odorata* is considered a pest in many countries by both conservationists and owners of plantation crops. A biological control programme of the weed has been initiated in Asia and in Australia a massive effort is being made to eradicate the plant from a few infested areas. Agriculturalists recently have suggested that *C. odorata*, although not a nitrogen fixer, may have positive effects on soil fertility in fallows. If this proves to be correct the promotion of this plant with small-scale farmers may well be considered (Baxter, 1995).

Management and prevention vs perceived benefits

In South Africa, where over the past couple of decades much effort has been put into controlling invasive plants, a number of heated exchanges have appeared in the literature. Arguments as to the benefits and costs of various invasive species to South Africa have pitted various types of conservationists against commercial interest groups such as foresters (Löckhoff, 1977) and the ornamental trade (Matthaei, 1999; van Sittert, 1999).

Biological control of IAS is sometimes opposed. For example, *Rubus fruticosus* agg. is an important environmental weed of south-eastern Australia and biological control has been instigated. Apiarists and berry canners opposed the release of a biocontrol agent (a rust) because they considered it a threat to their respective trade. At the same time managers of grazing lands threatened to illegally import the rust if the release programme was halted. An economic analysis found that the costs associated the blackberry were 40 times greater than the benefits. Before the conflicts were resolved the rust was recorded in Victoria (Field and Bruzzese, 1985). Many other examples of potential conflicts between the biological control of weeds, such as *Lantana camara*, and the beekeeping industry may be found in the literature.

Conclusions

The human dimensions of invasive woody plants reviewed above show that the history of introductions, the causes of introductions, and people's perceptions of invasive woody plants as well their impact are highly varied. Many aspects have been well reported but no exhaustive overview of woody plant introductions or of their impacts exists. The role of people's perceptions of invasive woody plants has been understudied and the few examples given above

clearly show that the topic is highly fragmented and deserves further study. Areas of investigation that deserve particular attention are the interactions between the media, the public and the scientists/conservationists, the views of indigenous people in developing countries, and the traditional uses of invasive woody plants. An area not addressed here is the importance of invasive woody plants in providing employment (e.g., woodfuel harvesting) and how this may affect local economies.

Some of the major implications of the variations documented in this review are:

- People's perceptions of an alien woody plant are based on their interest in and knowledge of their local environment. Communication and education are essential and great care must be taken to prevent the media from misrepresenting the issues.
- Conflicts of interest between various sectors of society are inevitable. In fact, even within interest groups (e.g. agriculture) sharp differences exist as to the value of a particular plant. An introduced plant may be viewed as a weed in large commercial monocultures whereas it may be considered to be beneficial in traditional small-scale agriculture (and vice versa).
- With the observed temporal changes in production and consumption, the value of an alien species to a particular interest group will change. Introduction of new species must take into account future changes in usage and demonstrate that detrimental impacts will be limited.
- When confronted with serious environmental problems local populations rely on outside help and development assistance traditionally focuses on the introduction of alien plants, even when the indigenous population (e.g. Rajasthan) is aware of the limited merit provided by the new species. Aid to developing countries clearly needs to thoroughly investigate the potential of native species and provide environmental management systems appropriate to local conditions.

The introduction of alien woody plants has been essential to the development of modern societies, but not enough care has been shown in identifying key positive impacts to justify many introductions. Furthermore, negative impacts have been largely ignored and these need to be addressed in order to avoid the disastrous impacts often observed, if future introductions are to have long-lasting beneficial effects on human societies. Instead of introducing alien species, whose long-term effects on humans are largely unknown, emphasis should be placed on enhancing the potential value of native species and plant communities.

Horticultural introductions of invasive plant species: a North American perspective

Sarah Hayden Reichard and Peter White

Abstract

Horticulture, the science and art of growing fruits, vegetables, flowers, and ornamental plants, has been an important source of alien species that subsequently have become invasive. The desire for novel exotic plants stretches back at least several hundred years, but the recent spread of botanical gardens, arboreta, nurseries, garden clubs, and horticultural society seed exchanges have greatly accelerated the spread of alien species of plants around the globe. The most successful way of dealing with this issue is to involve horticultural interests actively in dealing with the problem of invasive species of plants. The paper deals with possible objections by the horticultural trade and suggests several positive goals for collaboration. These involve botanical gardens taking a leadership role in the efforts to prevent more damage by invasive plant species, developing national plans to deal with invasive species in the horticultural industry, promoting the adoption of a code of conservation ethics by botanical gardens and nursery groups, and involving the gardening public actively in halting the further spread of IAS.

Introduction

The vast majority of plants used in agriculture, forestry, and horticulture in North America are not native to the continent. Most of the plants that have been introduced perform the purpose for which they are intended and therefore benefit humans in multiple ways. A small portion of introduced plants, however, escape from cultivation and become pests of natural areas. A recent study found that invasive plants, animals, and fungi are second only to habitat loss and degradation in endangering native plant species in the United States (Wilcove *et al*., 1998), with 57% of the imperilled species studied being negatively affected by invasive alien species (IAS).

While most introduced plants are not invasive, the majority of woody invasive plants in the United States were introduced for horticultural purposes – one study found that 82% of 235 woody plant species identified as colonizing outside of cultivation had a history of landscape use (Reichard, 1997), and an additional 3% were widely distributed for soil erosion control (although virtually all of the latter group were also introduced as ornamentals). It is likely that a smaller percentage of herbaceous invasive species were horticultural introductions. Instead, many of these species were introduced through crop seed contaminated with weed seed (Baker, 1986, Mack, 1991) or seeds in soil brought over from Europe as ship's ballast that was dumped at ports in order to load cargo (Baker, 1986). Between 57% (Kloot, 1987) and 65% (Groves, 1998) of the naturalized flora of Australia, both woody and herbaceous species, were intentionally introduced for horticulture.

The prevention of new introductions of pest plant species is a worthy goal, given their potential impacts, and one that is a least partially achievable. If we can examine primary pathways of species introduction, we can identify ways to modify those pathways to prevent problem plant introductions. If the past patterns of species being introduced as horticultural plants holds, we should expect that many more invasive species will be introduced by horticulture in the future. We should also expect that new and existing species will continue to be spread by horticultural pathways. This chapter discusses how such introductions occurred, with a view toward what might happen in the future and how we might work with the horticulture community to build bridges toward a solution.

A historical perspective on Western ornamental horticulture and plant exploration

Plants have been grown and traded since ancient times, perhaps as early as 8,000 BC (Huxley, 1978). Initially, the plants that were cultivated were probably those of medicinal or agricultural value. While they may have been arranged in aesthetically pleasing patterns, their purpose was utilitarian. The Egyptians, Greeks, Romans, Chinese, Babylonians, and other ancients, were known for cultivating ornamental plants, but the western tradition of ornamental gardening appears to have taken hold in the prosperity and overseas exploration of the Renaissance (Huxley, 1978). The development of the pure pleasure garden occurs when a culture achieves an excess of wealth, and it is often limited to the upper classes (Huxley, 1978). Before the 1560s, most plants used by Europeans were native to Europe and the Mediterranean basin (Hobhouse, 1992). The wealth and interest in the natural world that flourished during the Renaissance fuelled unprecedented plant exploration. For instance, a limited number of available interesting plants and a desire to have the finest gardens for his estate led an Englishman, Sir Robert Cecil, to send his gardener, John Tradescant, to far regions of Europe to discover new species in the early 1600s. He was thus among the first Europeans to explore new regions for plants of horticultural value in an organized way (Lyte, 1983). Tradescant, with his son, also established his own garden which grew nearly every plant species known in northern Europe at the time, and from which they sold plants (Hobhouse, 1992). The younger Tradescant continued to introduce new species until 1662.

In the early 1800s plant exploration became even more popular. Expeditions were led by David Douglas (early 1800s), Joseph Hooker (beginning in 1839), Robert Fortune (beginning in 1843), Frank Kingdon-Ward (early to mid-1900s), and many others to the far corners of the world in search of new and exciting species for the wealthy to grow. These individuals introduced thousands of species to Europe and Great Britain.

In the United States, plant exploration got a slower start. In fact, horticulture in all phases appears to have lagged behind Europe by about a hundred years (Manks, 1968). While several crop plants were introduced from Europe as early as 1565 (Huxley, 1978), and some ornamentals from Europe in 1631 (Hobhouse, 1992), most of the ornamental plant exploration by early North Americans centred on discovering and growing the flora of the continent (Ewan, 1969). However, there was at least one well-established private ornamental garden with plants imported from Europe to Philadelphia by 1698. The owner of the garden, John Bartram, became the American botanist to King George III and sent native American plants to England in exchange for European species, or other species that grew well in Europe (Dozier, 1999). The first experimental garden for crop plants was established near Savannah, Georgia, in 1735. The first commercial nursery doing intercolonial and international trade was started in 1737, in Flushing, New York, by Robert Prince. For nearly 100 years it featured both food and ornamental species (Manks, 1968). The first botanical garden was established in 1747, in Portsmouth, Rhode Island (Ewan, 1969). Thomas Jefferson, American president from 1801-

1809, was a horticulturist who also introduced several species. He may have been the first person to introduce *Cytisus scoparius* (Scotch broom) as an ornamental species (Wyman, 1969). It is now an aggressive invasive species in many parts of North America. Even though plants were not being actively introduced for horticulture, several non-native invasive species did make early appearances. Ewan (1969) reports a list published in 1672 of 23 "such plants as have sprung up since the English planted and kept cattle in New England."

By the early 1800s, global exploration and trade had increased, and industrialization increased prosperity and available leisure time (Dozier, 1999). In 1775 the Continental Congress decided to build a network of roads to meet the needs of the Revolutionary War. These roads opened up the interior of the rapidly expanding young nation to economic trade, including plants (Manks, 1968). Plants not native to the continent were finding their way to North America and penetrating inward from the port cities. Around 1827 the President of the United States, John Adams, asked all U.S. consuls to send seeds and plants to Washington so they could be grown for later distribution. The interest was chiefly in agricultural species (Wyman, 1968). By the mid-1800s new nurseries were opening and carrying larger stocks of ornamental plants. Most of the plants were still coming from Europe, which was being supplied by active plant explorations and breeding programmes (Wyman, 1968).

Despite their late start, several prolific plant explorers eventually worked from North America, mostly after 1900. Ernest Henry Wilson conducted four expeditions to China between 1899 and 1911, first for a British nursery and later for the Arnold Arboretum, associated with Harvard University (Slate, 1968). Beginning in 1920, Joseph Rock worked for the United States Department of Agriculture bringing in plants suitable for growth in North America and Hawaii. Rock also collected for the Arnold Arboretum. One of the most prolific explorers was David Fairchild, who in 1898, at the age of 22, established the Section of Foreign Seed and Plant Introduction within the United States Department of Agriculture. He travelled for 37 years, bringing back mainly new plants for agricultural use but also ornamental species. He also hired a number of explorers to work for his programme. One of these was Frank N. Meyer, who collected numerous Asian species between 1905 and 1916.

The Spanish and French also introduced plants into the parts of North America which they colonized, but these introductions are not as well documented as those made by British colonists. We do know that Spanish explorers brought peaches to the southeast United States in the 15th century (Wyman, 1968) and that Franciscan missions in California had a number of fruit and other plants as early as 1669 (Hedrick, 1950).

Little has changed in plant introduction methods over the past 400 years. Plant exploration remains active in the United States and was the focus of a special two-day symposium at the Chicago Botanical Garden, Chicago, Illinois, in March 1999. International seed exchanges are responsible for the movement of many species. These pathways are legal in the United States as long as they do not introduce insects, pathogens, listed noxious weeds, or species monitored by the Convention on International Trade in Endangered Species.

Botanical gardens and arboreta

A number of botanical gardens and arboreta still actively engage in exploration, including the Morris Arboretum in Pennsylvania, the Arnold Arboretum, and several others. Because of the expense of plant exploration, many gardens now may work together on an expedition. It should be noted that many of these expeditions are not oriented strictly toward collecting new species, but are also aimed at widening the gene pool of already cultivated species and those species that may be threatened in their native habitats (Meyer, 1987).

Sometimes the plants collected by exploration expeditions may be used only in display, but in most cases the plants are distributed, both by selling plants for fund-raising or supplying cuttings or seeds to local nurseries. Most botanical gardens and arboreta have public service as

a key component of their mission, and introducing new plants for landscape use may fit their service requirements. If care is taken, exploration by gardens does not have to result in the introduction of invasive species. In particular, because plant sales are not a major part of most gardens' income, the plants do not need to be released immediately. Unlike most commercial enterprises, botanical gardens have the opportunity to hold species in the garden for extended periods of time to observe their opportunistic behaviour. The delay in release for sale may not be entirely satisfactory, however, especially for woody plants, which often have a long juvenile period before seed production begins. Invasive plants may not begin to invade for many years (Scott and Panetta, 1993; Cousens and Mortimer, 1995; Kowarik, 1995), a condition known as a "lag time," and thus their ability to invade may not be detected by holding in the garden for several years. Delaying introduction may be helpful, though, in preventing some invasive species (especially herbaceous species) from being released to the public. Also, many gardens and arboreta are associated with colleges and universities and could work with biology faculty and students in assessing invasive risk and monitoring the species.

Many botanical gardens participate in formal seed exchanges, with each garden devising an "Index Seminum" or list of available seeds, and exchanging lists with participating gardens all over the world. Botanical gardens and arboreta request seed of plants they want to include in their collections and the listing garden sends it to them. A few botanical gardens have chosen to mark species on their list that are known to invade somewhere in the world and urge caution in growing the plant. For instance, the Washington Park Arboretum, in Seattle, Washington, has noted, "The Washington Park Arboretum is concerned about the impact of alien plant introductions on local native plant populations. Those species indicated with an asterisk have been reported to naturalize in some regions. It is assumed that institutions or individuals receiving seed will take appropriate steps to evaluate the invasive potential of all plant introductions." A more extreme, but also probably more effective, approach is that of the North Carolina Botanical Garden, which has a native plant collections policy. They will not send seed to anyone outside their bioregion, thereby preventing a possible contribution to the invasive plant flora. Similarly, the Lyon Arboretum in Honolulu does not issue an Index Seminum and exchanges plants with botanical gardens outside Hawaii only after careful consideration (C. Lamoureux, 1999, pers. comm.).

Nurseries

While the first nursery in the United States was established in 1737, the garden centre as we know it is part of the post-World War II economic boom (Dozier, 1999). Most retail nurseries buy plants from wholesale growing facilities; however, some retail and wholesale nurseries have active plant exploration programmes. The expeditions may include both collection of plants from the wild and purchases of local favourites from foreign nurseries (D. Hinckley, 1999, pers. comm.). Because they are commercial concerns they may be less inclined than botanical gardens to hold species before release to the public, needing the income to recoup the expense of the trips. Wholesale nurseries may sell all over the country, using their own or commercial trucks to deliver the plants. Most retail nurseries sell to the local area only, meaning that if a species becomes invasive it may not have been too widely distributed for rapid response control efforts to be effective. Some retail nurseries, however, are primarily or totally mail-order. These nurseries send species all over the country, using the postal system and commercial shippers as efficient invasive plant dispersers. The result of wholesale shipping or postal mail-order is that the probability of an invasive plant reaching an appropriate climate for invasion is increased and control efforts may be extremely difficult. An invasive species could thus reach and begin spreading from widely separated parts of the continent. At least one popular mail-order nursery, Heronswood Nursery in Washington state, is taking some steps to combat this problem. They have recently assessed their current catalogue and voluntarily

withdrawn some known invasive species from sale, while others are marked as high-risk species based on their performance elsewhere and buyers are cautioned to remove the plant if it starts to spread vigorously. While not ideal, this approach may prevent the spread of some known invaders and the escape and establishment of some new pests and will help to alert the plant-buying public of their role in preventing the spread of invasive species. In August of 2000, Heronswood also took the bold move to inform their customers in the state of Florida that because they specialize in newly introduced species and because Florida has such serious problems with invasive alien species, they would no longer sell any species to anyone in Florida (D. Hinckley, Heronswood Nursery, pers. comm., 2000). This move has been very controversial among horticulturists and has certainly increased the dialogue.

Garden club and horticultural society seed exchanges

Botanical gardens and arboreta are not the only institutions to exchange seed. Groups such as the North American Rock Garden Society and the International Bulb Society also offer their members seeds through an exchange. Moreover, numerous more informal seed exchanges managed by individuals have sprung up over the Internet. A quick check of some of the exchange and sale lists on the Internet reveal that many recognized invasive species are being offered, including those on state and Federal noxious weed lists. It is doubtful that these regulatory lists are commonly consulted before seed is sent in either formal or informal exchanges.

The seed trade industry

The American Seed Trade Association (ASTA) is one of the oldest trade associations in the United States, reflecting the country's agrarian past. Seed producers provide seed for many purposes, including horticultural uses such as ornamentals and revegetation efforts and agricultural uses including food crops and pasture grasses. While they do not do much exploration for new seed, they do ship seed all over the country and export out of the country. In October, 1999, they issued a position statement on invasive species (it may currently be viewed at <http://www.amseed.com/ documents/invasive102899_1.html>. The statement expressed support for protecting the environment, but protests the proliferation of lists of invasive species (without differentiating between regulatory and advisory lists). They feel that many species considered invasive also have beneficial uses that must be considered. The final paragraph of the statement reads, "ASTA will oppose and challenge, however, any efforts to list as 'invasive' or otherwise jeopardize the legitimate use and viability of species beneficial to agricultural crops, or when used for turf, conservation, or ornamental purposes."

Other horticultural pathways

Not all horticultural uses are strictly ornamental. Many people grow medicinal and culinary herbs. The interest in herbal remedies is resulting in increased attention in the growth of some invasive species with medicinal uses. For instance, St. John's Wort (*Hypericum perforatum*) is a noxious weed with harmful effects on livestock as well as impacts on natural areas, but it is also gaining enormous popularity as an anti-depressant. It is now being grown legally as an agricultural crop in Washington state, where it is also listed as a noxious weed. It was downgraded from the list of species for which control is mandated to a list of species that are considered legally noxious, but control is not required. This change accommodated its growth for the medicinal herb industry.

Several aquatic weeds have been introduced as decorations and amendments to personal aquaria, including such notorious invaders as *Myriophyllum spicatum* (Eurasian milfoil), *Salvina molesta*, and *Egeria densa*. Uninformed people sometimes dump their aquarium water, containing the plants, into local water sources and many of the plants survive and multiply. *Hydrilla verticillata*, a very aggressive aquatic weed in the south, was probably introduced to provide a domestic source of this plant for the aquarium trade (U.S. Congress, 1993). Similarly, species such as *Eichhornia crassipes* (water hyacinth) were introduced for aquatic gardening and have escaped to have serious consequences (Williams, 1980). Aquatic weeds introduced for horticulture are often overlooked by those focusing on the larger terrestrial plant trade, but horticulture should be considered to be a critical pathway of pest species introductions, especially as water gardening appears to be increasing very rapidly (Kay, 2000). Because of the interconnected nature of many aquatic systems, the species can spread quickly and become very expensive to control. Upwards of $100 million per year is spent to control mostly non-native aquatic invasive plants (U.S. Congress, 1993).

Many species have been introduced to reduce soil erosion. The United States Soil Conservation Service (now the Natural Resource Conservation Service) was established in 1933 to reduce soil erosion caused by poor agricultural practices. It aggressively promoted the use of several species, such as *Elaeagnus angustifolia* (Russian olive), *Rosa multiflora* (multiflora rose) and *Pueraria lobata* (kudzu). Although each of these species originally had ornamental uses and were introduced for that purpose, they were more actively spread by the Service.

The United States Department of Agriculture estimates that in 1997 (the most recent year for which there are figures) the floriculture and horticulture industry had cash receipts of $11.2 billion (USDA, 1999) in the United States alone. Gardening is consistently listed as a top hobby in the U.S. Horticulture is an industry that is important to consumers, to improving the urban environment, and to the economy. It is therefore critical that industry and customer needs are understood in efforts to reduce horticulture as a pathway of invasive plant introduction and spread. It is also important that conservationists, botanists, and ecologists work with the horticulture industry to find ways to help them identify and find alternatives for invasives, rather than blame them for the introductions that have happened in the past.

Ecology, conservation, and horticulture – working together

Is it realistic to expect that change in horticulture as a pathway of invasive plants will occur? Although it is difficult to say what form change will take, it is very probable that it will happen. Change in procedures and policy occur when a critical mass of people determine that a problem or threat exists and demand solutions. The change may come from within the horticulture industry or it may be regulatory, or it may be both.

It is conventional wisdom that most human beings resist change; horticulturists are like all other humans in this respect. They have been introducing plants in essentially the same way for 400 years, and the romance of plant exploration is as strong as that of any other type of exploration. Over the past several years, however, with increasing evidence about the impacts of invasive species, nurseries and botanical gardens have been open to change (see Morin, 1999 and the "Invasives Roundtable" in the July 15, 1999 issue of *American Nurseryman*).

Creating a divisive "us-versus-them" mentality will do nothing to resolve the conflicts that often seem to develop between ecologists working on protection of natural areas and horticulturists wanting to bring new plants into the landscape palette. Dialogue between the two groups will lead to solutions, while finger-pointing will not. It is therefore important for

ecologists to understand some of the key objections that horticulturists have and to address them:

Objection 1. Not growing invasive species means that we can grow native species only, and that is too limiting. Besides, it follows the Nazi dictate that only German native species should be grown (Pollan, 1994).

It is important to emphasize that the issue is *not* natives vs. non-natives but invasive aliens vs. non-invasive species, including most aliens. Whether it is beneficial to promote the use of native species in horticulture is a separate issue and a controversial one. By confusing the two, those who support anti-invasive species policies have gotten caught up in the backlash against the native plant movement (Koller, 1992, Pollan 1994), an unproductive detour. Invasive non-natives are a small portion of the total group of non-native species available to horticulturists. There is no "ethnic cleansing" aspect to the argument that non-natives that are used in the landscape should be non-invasive. Plenty of non-native species would still be available and grown.

Objection 2. Invasive plants invade only disturbed areas, such as those around roads and shopping malls.

Many invasive plants do exploit the reduction in competition following disturbance. This is not always true, however. Several species, such as *Alliaria odorata* (garlic mustard), *Hedera helix* (English ivy), and *Geranium robertianum* (herb robert) appear to invade and affect areas with no apparent disturbance. And, although it has been speculated that areas of low species richness are more easily invaded (Darwin, 1859; Elton, 1958), a recent study found that in many locations, areas of high species richness are invasible (Stohlgren *et al*., 1999). This study found that invasion may be more closely related to available resources in the community (which may be high in areas of high biodiversity) than to species richness.

It should also be understood that disturbance is a natural part of many ecosystems (White, 1979; Pickett, 1980; Hobbs and Huenneke, 1992). Fire, hurricanes, landslides, floods, earthquakes, and many other events are disturbances that, it is increasingly becoming clear, are crucial to the maintenance of the systems in which they periodically occur. Introduced invasive species capable of exploiting disturbance may be able to recolonize more rapidly than native early successional species and, because the invaders often reach reproductive age quickly and reproduce vegetatively (Reichard, 1997) they can increase the population rapidly, to the point of excluding the native species.

Objection 3. "Invasive plants" can also be native species.

Certainly, some native plants can be considered invasive. When they are considered invasive they are managed, just as non-native invasive species. However, native weeds do not reduce global plant diversity by replacing healthy native plant communities with aggressive non-native species. The worst invaders, with the highest impact, are intercontinental.

Objection 4. Invasions are natural occurrences. Plants have always migrated into new areas. (Related objection: humans are natural animals, so why should we be considered as unnatural plant dispersers? And aren't we the most invasive organisms of all?)

As with so many other "natural" environmental processes, humans change the scale of species introductions. An example is this is easily seen in Hawaii, the most isolated island chain in the world. It has been estimated that the natural rate of successful introductions resulting in "wild" populations was one species on average every 100,000 years (Fosberg, 1948), with the 1,094 native flowering plants there now originating from approximately 270-280 successful colonization events (Wagner *et al*., 1990). When the Polynesians colonized the islands approximately 1,500 years ago they brought several species with them and the rate increased to

one introduction every 50 years. In contrast, approximately 4,988 species (both angiosperm and gymnosperm) have been introduced to the islands since European colonization, a rate of about 22 taxa per year (St. John, 1973). At least 869 of the introduced species have established in the last 200 years (Wagner *et al*., 1990). At the recent rate of introduction, native communities are swamped and overwhelmed with new species that are often very aggressive. Hawaii, because of its isolation and island ecology, may be an extreme case, but the rate of introductions carried out by humans over the past several hundred years around the world is clearly far higher than the "natural" rate of dispersal.

The related objection may also be answered with a similar explanation. The rate at which we are dispersing plants is *not* natural. For most of human history, humans moved relatively few plants around by migration by foot, pack animals, or small boats and across relatively small distances. It did not involve hundreds of jumbo jets and container ships moving people and cargo around daily. And yes, humans are invasive organisms. But a harmful invasive plant transported by an invasive animal does not change its effect.

Finally, it should be pointed out that natural migrations usually occur into contiguous areas and within natural barriers within the "coevolutionary envelope," in which they are usually accompanied by the simultaneous movement of their natural enemies, including specialized pathogens and herbivores that attack and/or feed on one or a few plant species by contrast. Most harmful invasions are across broad discontinuous landscapes.

Objection 5. Anti-invasive policies are bad for the nursery industry.

This statement is not accurate for a number of reasons. First, consumers have expressed a preference to be informed of invasive ability so that they do not purchase invaders (Reichard and White, in press). If the nursery industry wants to continue to be perceived as a "green industry," it will need to recognize this. Second, invasive plants are a small part of the sales of most nurseries, so removing them from sale is unlikely to have a significant effect on their bottom line. Third, removing invasive plants from sale could actually stimulate sales, if handled correctly, because replacement plants would need to be promoted and sold. Countless landscapes use *Hedera helix* (English ivy), an invasive species along the west coast and parts of the east coast of North America, as a groundcover. What if consumers are encouraged to remove that species and plant with another non-invasive species? Finally, advertising that a nursery is selling only non-invasive species could draw customers in, as the survey discussed earlier revealed.

Objection 6. I can grow invasive species because I can prevent them from setting seed or growing vegetatively outside my property.

This is a naïve, although perhaps well-intentioned, thought. It is possible that some smaller plants may be controlled for a time by removal of seed heads and confinement of rhizomes, but it is impossible for larger plants and over a long period of time. Larger plants may grow to a size beyond the reach and capabilities of the grower. And over time, the grower may forget, be on vacation or ill during fruiting time, or move away and sell the property to a less informed or vigilant individual. A destructive invasive species should not be grown.

Objection 7. Restrictions against invasive plants may be needed, but they should only be done on a regional or state level.

The answer to this is yes – and no. It is true that most species do tend to invade only certain areas of a large country. For existing invaders it may be possible to restrict their sale only in the regions where they can escape and establish outside of cultivation. Each bioregion could have a coalition of ecologists and horticulturists to discuss which species could be reasonably removed and the timeframe in which to do it. However, for new species not yet introduced or established in the country, but judged likely to escape and become a pest in some region, the

restrictions should be enacted on a national level. North America (and most other continents) include just about every type of climate and soil imaginable. Once a species has entered the U.S., it may spread very quickly through the horticultural channels described above. Thus, the probability that it would arrive in the region to which it is best suited to invade is high. Screening of new introductions must be done with that in mind.

Conclusions

The burden of the solution to the introduction of invasive species by horticulturists does not necessarily fall on the shoulders of that industry. It is in various groups and disciplines working together and adding their strengths that some solutions may be found. In the summer of 1997 the American Nursery and Landscape Association and the Weed Science Society of America brought together ecologists from The Nature Conservancy, the University of Washington, and the University of Florida with representatives from a number of horticulture service and trade organizations to discuss possible areas of agreement and collaboration. The grounds for these diverse groups working together have been laid in this effort and a number of state and regional dialogues. The dialogue needs to continue, with several positive goals in sight. These include:

- Increase education for and by the horticulture community. As more data about the impacts and biology of invasive plant species are collected and analyzed, this information needs to be shared with horticulturists. They need solid facts upon which to make informed decisions. And, in many cases, horticultural enterprises are ideal for transmitting that information to consumers. There also needs to be more effort to involve and educate garden writers, the "tastemakers" (Dozier, 1999), so that they do not support problem plants in their writings and so that they bring the issue of invasions into their writings.
- Enable botanical gardens to take a leadership role in the efforts to prevent more damage by invasive plant species. The American Association of Botanical Gardens and Arboreta has sponsored symposia on invasive plant species at its annual meetings for the last several years. At the 2000 World Botanic Gardens Congress an effort to develop a "Code of Conservation Conduct for Botanical Gardens" was begun and development is currently continuing over the Internet. Most botanical gardens and many nurseries have education programmes and publications and could easily include classes and articles on new invaders in the region, how to avoid buying invasive species, and so on.
- Intensity of the engagement of horticultural businesses that may not introduce new plants, but continue planting existing invasive species. Most effort has been placed on getting the message to nurseries and botanical gardens, but those specifying and planting invasive species should be a priority for inclusion in finding solutions. This includes landscape architects and landscape gardeners.
- Remove agreed-upon invaders from sale. Such an approach may be done regionally, with groups of ecologists and horticulturists working together. The Exotic Pest Plant Councils forming in many parts of the country may be the appropriate organizations to take the lead, working with state nursery associations, as has been accomplished in Florida.
- Give encouragement and assistance to horticulturists in prescreening new introductions. Where prescreening is beyond the resources of nurseries or botanical gardens, ecologists should attempt to work with the nurseries to use best-practice methods of risk assessment.
- Develop national plans to deal with invasive species in the horticulture industry. Australia released a draft plan in February 1999, featuring development of regulations, education programmes, plant lists, logos and slogans, and plant labelling. Other

countries should develop and implement such a plan, using input from weed scientists, ecologists, government officials, and horticulturists.

- Promote a "code of conservation ethics" to botanical gardens and nursery groups. Such a code of ethics might encompass several conservation issues, but specific to the issue of invasions, might include not smuggling material, monitoring to assure that imported material is free of disease and contaminants, and notifying recipients of seeds in exchanges that certain species have demonstrated invasive ability and that due caution should be exercised. As noted, efforts have begun to do this for botanical gardens and plans are underway to develop them for the nursery industry in the United States.
- Involve the public in eradication efforts in natural areas. This is an important way to increase public awareness of invasions, so land managers should encourage public participation in weed control, especially in high profile areas. A survey in the southeast found that 62% of the those who could name a plant invader knew of it through personal observation (Dozier, 1999). Participating in control efforts will also impress people with the difficulty in eradicating a "garden plant gone bad."
- Finally, educate the gardening public. This remains perhaps the most critical need in the future. Better communication from ecologists to the public about which species are causing problems will discourage people from buying them. This means ecologists should be willing to write articles for the popular press, give talks to garden clubs, and/or work with the horticulture community to get information to them. Gardeners are often unable to understand that buying a plant for their backyard may contribute to biological invasions (Colton and Alpert, 1998). It is important that efforts continue to integrate ecological and horticultural perspectives.

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The understorey of human dimensions in biological invasions

George W. Staples

Abstract

People frequently tend to move species from one place to another, possibly because they have an innate desire to have other species of organisms near them, irrespective of their cultural origins. However, the rise of global consumerism has greatly increased the flow of plants and animals around the world, driven by modern transportation and communications technology. This has been accompanied by growing urbanization, where people are disconnected from the land and the ecological processes it supports; people living in cities may have only a very slight understanding of the native or alien characteristics of the species around them (indeed, they may not even care). Management of IAS needs to take into consideration the human dimensions, including cultural and political elements, in order to overcome apathy, scepticism, and ignorance. Successfully dealing with IAS problems will require bringing in other parties affected by the issue, including human health, commerce, and agriculture.

Introduction

People have been moving plants and animals around the globe since the dawn of human existence (Mabberley, 1999). Some of those species were moved intentionally and others were accidental hitchhikers. Some survived in the new habitats; others died out. Of those that survived, dubbed alien species because they are not native to the place where human activity put them, some managed to survive and reproduce in populations that did not make a discernible impact on the environment, while others, sometimes quickly, sometimes slowly, began to spread and undergo dramatic population growth and range expansion. These latter alien species are called invasive alien species (IAS) because of their ability to spread aggressively, impact the environment, commerce, agriculture, human health and quality of life, or any combination of these.

That, succinctly put, is the problem. It is the purpose of the Global Invasive Species Programme to work toward an international approach to facing this complex and multi-tiered problem. While scientific and government awareness have been increasing for a number of years, the recognition that the invasive species problem is at its heart a human problem has been a recent one. If we are to gain some understanding of the human dimensions of the IAS problem, and then do something about it, then we must step back from the details and try to see the larger picture. To paraphrase an analogy, "One can't see the forest for the trees." And so it is with alien species issues: the upper tiers, closer to us, obscure what is underneath, much like the canopy of a tall forest obscures the ground beneath. The understorey, where the roots are, is hidden far below the middle and upper tiers of the canopy. It is the goal of this paper to peer

beneath the more familiar levels of the invasive species problem, already adequately described by others, to appreciate the problem's deeper root causes and driving mechanisms. In order to do so, it is necessary to step back from invasive species in the narrow sense, and consider the bigger picture of species movements mediated by humans, some of which species prove to be invasive after the fact.

The considerations begin with two questions:

"Why do people manifest such a pervasive need (or desire) to move plants and animals from places where they are native to places where they are not?"

"In the face of mounting evidence that alien species can have negative impacts on ecosystems, economies, lifestyles, and biological diversity, why do people resist efforts to control, regulate, or restrict transport of alien species?"

The first question is addressed in sections 2–6; the second question is addressed in sections 7–8. The thoughtful reader will use these remarks as a starting point for further reflection and discussion of the underlying causes for human behaviour relative to alien (including invasive) species. Understanding and redirecting those underlying causes are vital to making meaningful changes to the ways humans think about, act upon, and react to invasive species issues.

The biophilia hypothesis

Biologist Edward O. Wilson (Wilson, 1984) has postulated that human beings have an innate tendency to focus on life and lifelike processes, a condition he terms biophilia. He alludes to a human predilection for close association with other (non-human) species, manifested in a multitude of ways. Humans will expend great effort to modify their environment to fit an ideal that is eerily uniform across cultures, across geography, and across time, an ideal that bears striking similarity to the plains of Africa. Wilson also touches on human practices of keeping pets, on the biological study of life forms and natural histories, and even a conservation ethic, as human expressions of biophilia.

If we take Wilson's biophilia hypothesis to be true (and while there is much circumstantial evidence from a variety of disciplines that seems to support it, in the end it may not be provable as fact) then is it possible that one manifestation of human biophilia is a need (or desire) to have other, non-human species nearby, living in close association with people? Humans appear to need other species near them. For evidence one need only look around. No matter where in the world one might be, there will be evidence of human affinity for non-human species: from the meanest hovel in a teeming slum to the most palatial mansion in a city, you will find plants cultivated for colour, fragrance, edible or useful properties. There might be pet dogs, cats, or other vertebrate animals (fish, birds, reptiles) in the home. On a larger social scale, most urban areas have aquariums, zoos, botanical gardens, and nature parks. When questioned, people report that they enjoy having plants and animals nearby, it is a source of pleasure.

Is it possible that human beings have an innate requirement to have other species near them? Are humans genetically programmed, "hard-wired" in some way, that they have such a powerful desire to have other species of organisms near them? Could this be a behaviour that is so much a part of our makeup that it might be described as diagnostic for recognizing *Homo sapiens?* If this idea is not too farfetched, then it places human movement of plants and animals in a different light. While there are commercial, economic, agricultural, and even conservation motives for transporting species, there is also the possibility that these motives have at their roots something that reaches to the very core of human nature. If this were the case, then human movement of species may not be a behaviour that can be completely eliminated, but it might be possible to redirect it into channels that have less damaging consequences than what we currently face.

Perhaps the social sciences, ethology, and anthropology can shed light on the human affinity for other species, which leads to moving them around. If it is possible to ascertain the

underlying causes for the behaviour, then it is possible to know whether it can be changed, or even eliminated.

Is there a cultural component to the human need to move species around?

The historian of science, Alfred Crosby (1986), has meticulously documented the history and consequences of the mass translocations of plant and animal species around the globe by Europeans and their colonial descendants from 900AD until 1900. While European peoples have certainly moved exceptionally large numbers of species during the last 500 years or so, they were not the first to transport species over great distances. David Mabberley (1999) has pointed out that the earlier trading empires of the Javanese in Malaysia, the Arabs in the Middle East, India, and Africa, and the Chinese throughout eastern and south-eastern Asia all moved plant and animal species around the Old World tropics, centuries prior to the advent of Europeans. Anthropologist Patrick Kirch (Kirch, 1982) has done the same for the Pacific and pointed out that the Polynesians who settled Hawaii wreaked ecological havoc on the natural ecosystems they encountered there, transforming the pristine landscapes through the introduction of alien plants and animals as well as by the use of fire to clear land for swidden agriculture.

Some scientists have tended to accept Crosby's work as evidence that Europeans have been by far the worst perpetrators of alien species introductions, that they have some cultural trait that makes this possible. This is a misrepresentation at the least and an injustice at worst. Crosby's model, developed for temperate climate zones and organisms, does not hold up as well for the tropics. And it is important to bear in mind that we know a great deal more about the European translocations of species because they are the most recent and (perhaps) because they are documented in European languages readily accessible to Western scholars. It would be fascinating to know what is recorded about the movement of plants and animals around the Old World in literature in Russian, Chinese, Arabic, Hindi, and Pali. It could be that our understanding of historical movements of alien species is imperfect due to a language barrier that prevents access to information.

One small footnote bears mention: the earliest scientific descriptions and narratives assumed that species were native to the places where European chroniclers and collectors first encountered them. This assumption was not infrequently false. As Mabberley has stated (1999: 9) " … European knowledge was confined to objects of commerce, … and to the plants and animals around the coastal and riparian settlements of the traders. For that reason, plant knowledge at first focused on pantropical weeds and the plants of the seashore, a remarkably uniform vegetation throughout the Tropics." Concepts such as *native* and *introduced* were imposed by Europeans from the time of their own arrival in a place, ignorant of the history of prior human activity there. Species were frequently assumed to be native when in fact they were aliens brought by earlier waves of traders from elsewhere in the Old World. Some of this misinformation persists in the botanical literature to this very day, having become so entrenched in the scientific canon that it is impossible to dislodge. Thus one must be wary of too strict a reading of terms such as indigenous and alien even today.

Finally, it is important to distinguish between past activities of a particular cultural group, and the present events that are reshaping the world's biota. During the great translocations of the sixteenth through the eighteenth centuries, people brought useful plants (crops, economic products for trade) and animals (livestock) with them because they were necessities for survival. To a much lesser degree, ornamental plants and pet animals were brought along as reminders of home. While it is possible and perhaps easy to identify particular cultural or political groups that were responsible for moving species around the globe in the past, at the

present time the driving force is trade and commerce rather than politics or national affiliation. Today people move ornamental plants, exotic pets, and unusual/ethnic foodstuffs around the globe because of the powerful commercial demand for such products in the global marketplace, based on people having sufficient income to afford these luxuries.

Thus it seems evident that no cultural or geopolitical group has a greater proclivity for moving species around than another. The European translocations of species were merely the most recent and by far the largest of several waves of introduction and naturalization mediated by humans. However, it is undeniable that the numbers of species moved by Europeans escalated dramatically and rapidly compared to those of previous centuries. And the numbers continue to increase today, world-wide and irrespective of ethnic or cultural affiliation. What makes this possible? The answer is twofold, in part the explosion in technological development and in part the manipulation of the buying public by clever advertising.

The twofold impact of technology

Technology has had a twofold impact, first through transportation and second through communication.

Transportation technology

As mentioned earlier, several waves of translocation for alien species have been mediated over time by various cultural or ethnic groups. Each wave seems to have moved larger numbers of species and over greater distances, due primarily to changes in transportation technology and skill. As Mabberley (1999) describes it, "This trade in plant materials exploded when, in the Malay Archipelago, there arose a skill in seamanship unparalleled until modern times. Thanks to this advance 2,500 years ago or earlier, the islands of the southwest Pacific had been settled. … before 589AD, incense wood (and ivory) was being traded from the Malay Archipelago to China." Technological advances in ship design, rigging, and sailing technique advanced over a period of centuries before wind-powered water craft were replaced by steamships in the 1800s. Then in the early twentieth century, airplanes became a reality and within a few decades modern jet travel became widespread and the world continued to shrink. Rapid, safe, economical air transport has changed the worldwide transport of species dramatically. Whether intentional or accidental introductions, modern jet travel has made it easy to move plants and animals around the globe in hours rather than days or weeks. This has made possible the global movement of species in unprecedented numbers and has had many unforeseen consequences.

However, air transport alone is not the problem; all major transportation modes (railways, highways, and shipping) have contributed to the spread of IAS. In one example currently being monitored in Hawaii, a floating military dry dock that was towed from San Diego, California, to Pearl Harbor, Hawaii, was found to have a large number of eastern Pacific species of seaweeds and benthic marine invertebrates attached to the hull. Such wholesale transport of an entire benthic community is commonplace today and such inadvertent introductions of alien species have been a major source for invasive species in marine ecosystems. Surveys completed in 1996 revealed that of 419 taxa in Pearl Harbor, 23% were introduced or cryptogenic (of uncertain origin) (Coles *et al*., 1999). By comparison, Honolulu Harbor (Keehi Lagoon) has 17% introduced or cryptogenic taxa: (L. Eldredge, pers. comm.). These figures are indicative of the global scale for alien species introduced through maritime shipping.

It seems evident that transportation technology has become an enormous part of the global problem in spread of IAS. What remains to be seen is whether technology can be harnessed to assist in curbing their further spread and impacts.

Communications technology

The explosion in communication technology has been a further factor in IAS issues, in several disparate ways. As noted below, advertising via diverse modern communications media sends and reinforces powerful messages about what is trendy, beautiful, luxurious, tasteful, and so forth. Communications technology has made it possible to transmit advertising through printed material, radio, television, telephone, video, interactive computer programmes, the Internet, and the World Wide Web, among others. New forms of communication continue to appear as fast as the technology advances. This global phenomenon has had an impact on IAS issues in several indirect ways.

First, the importation of alien species of garden plants has entered a new phase, due in part to the ready availability of seeds through mail order and Internet-based companies that sell directly to the customer (the "johnnycyberseed.com" phenomenon).

More subtly, communications media can create powerful imagery of what a place is like that fuels people's demands to experience what they have been led to expect. For example, in Hawaii, visitors have been led to expect a lush tropical paradise, with luxuriant foliage, bright coloured flowers, splashing waterfalls, and singing birds. Driven by this societal expectation, the tourist industry has replicated the fantasy image by creating verdant rain forests in the midst of coastal leeward deserts, replacing native flora with imported species that better fit the public's image of what is found in a rain forest. It is noteworthy that the indigenous angiosperm (flowering plant) flora of the Hawaiian Archipelago numbers 1,029 species, the naturalized angiosperms number 1,072 species (Eldredge, 2000), and the introduced aliens number in excess of 10,000 species (G. Staples, unpublished). The media imagery of Hawaii invented during the last 50 years has been a hidden factor in the meteoric rise in the number of alien plant species introduced, as the visitor industry worked to create the tropical island paradise that visitors came to expect.

Yet another aspect of the explosion in communication technology is the ease with which people are able to disseminate opinions and "junk science" over the Internet, through CD-ROMs, video, and other means. Among those who dispute the existence, severity, and extent of the invasive species problem, the ease with which alternative points of view can now be disseminated worldwide to those who are uninformed about the issues has greatly complicated efforts to educate and enlighten them. In the free-for-all of information available via modern communication, a hodge-podge of legitimate information, pseudo-science, and out-and-out misinformation is freely available, and many people today cannot distinguish facts from fancy. This issue of uninformed, misinformed, and unbelievers leads into yet another human dimension that plays a critical role in IAS issues.

Advertising, marketing, and the rise of global consumerism

Beginning in the early decades of the twentieth century, roughly the 1920s, marketing and advertising executives in the USA devised and implemented a new strategy to motivate the American public to buy more goods. This calculated "campaign for modernization" created a pattern of replacing the status quo with new things in American life. New was equated with better, and better meant you were societally successful. The development, implementation, and social consequences of this advertising campaign that changed the way Americans think and, more important, the way they buy, has been well documented and the ongoing consequences are still being felt at all levels of American society (Meyers, 1984; Marchand, 1985). And due to the rapid rise in capitalism around the globe in recent decades, the compulsion to buy has stretched to many countries that have joined the global marketplace. This trend has played a

role in the spread of alien species around the world and has indirectly been a major factor in the increase in invasive species.

Initially this advertising campaign was directed to everyday items people used in daily life. Later it was expanded to clothing, hair styles, ornamentation (jewellery, accessories) and to "big ticket items" such as homes, automobiles, and electronic devices of all kinds. As time passed, advertising has become a fact of life and it now directs choices in virtually everything people buy, including a number of specialty items that can include alien species, such as ornamental plants and exotic pets. Along with the targeted species that are deliberate introductions, associated weed, pest, and disease-causing species often are brought along inadvertently.

In contrast, mainstream agriculture has taken a slightly different course in the trend to create and aggressively market new products, with two dissimilar results. On the one hand the development of new super strains of crop plants has increased yields dramatically, yet caused a loss in genetic diversity as land races that are adapted to local microclimates and growing practices have been replaced by monocultures based on single genetic races. At the same time, the weeds, pests, and pathogens that are inadvertently selected along with the super strains of crops are also being "improved" and when these alien species are transported along with the crop species their introduction can have disastrous consequences.

Over the past two decades interest has exploded in the USA toward ever more exotic and unusual foodstuffs, spices, cosmetics, and food supplements/herbal remedies (= neutraceuticals). This has created a whole new realm of agricultural possibilities for those willing to introduce, grow, process, transport, and market plants that fall outside mainstream, monoculture-based agriculture. This trend has compounded alien species problems because it further increases movement of alien plant species, both the desired species and their weeds, pests, and diseases.

The search to find new species for sale and then the marketing drive to sell them have been strong forces in the ornamental plant trade, in the exotic animal (pet) trade, in the specialty foods marketplace, and in the neutraceutical industry. If there is to be any hope for controlling the flow of invasive species worldwide then it will be vital to come to grips with the powerful forces of marketing and advertising that create and fuel the demand for new species in these areas of commerce. Consumers in developed countries obviously have disposable income to spend on leisure and hobby activities, and many of those expenditures are made in activities such as gardening, keeping pets, health and fitness, and cooking. It remains to be seen whether marketing and advertising can become allies of the Global Invasive Species Programme in stemming the flow of invasive species through commerce.

Declining environmental awareness in the developed world

Among the developed countries of the world, several generations of the population have now grown up living in urban environments and are disconnected from the land and the ecological processes it supports. These individuals are largely unaware of their own local environment and frequently do not know local biota from direct, firsthand experience. While many people enjoy outdoor sports and recreation, comparatively few are able to recognize species native in areas where they live. This disconnectedness has been one factor in the decreased ability of urban dwellers in general to differentiate native from non-native species in the area where they live.

Communication technology, despite its many positive applications for educational needs, has played a role in disconnectedness. For many children raised in urban areas, their experience of the biological world is limited to, or perhaps is more attractive through, technology such as educational television, home video, interactive computer programs, and surfing the Internet.

Sadly, they do not have the experience of planting a vegetable garden, digging earthworms to use for fish bait, or feeding chickens on a farm during summer vacations. They may know something about these organisms, but their knowledge is intellectual rather than experiential. And this fuels the disconnectedness between people and the environment.

These factors intersect in something that is at the core of the human dimension of IAS issues: many people have trouble understanding the distinction between "native" and "alien" species. The concept of natural distribution vs. human-mediated distribution, so important to scientists, is not discernible to the general public. In fact, one cannot tell if a species is native or not just by looking at it. This requires recourse to reference materials unless one is well informed about the biota and knows its history and biology. And this distinction is not always easy to make, given how many species have been translocated during the long history of human activity on the planet.

Nevertheless, the general public has trouble distinguishing native species from aliens. To cite one example from Hawaii, tourists are routinely driven on round-island bus tours that describe the beauty of the "Hawaiian rain forests" through which they pass. Hundreds of thousands of visitors per year leave Hawaii with the belief that what they saw was native to the islands. Sadly, many residents also fail to recognize that more than 90% of the species comprising these low elevation "rain forests" are not native to Hawaii. Because they are unable to distinguish native from alien species, they fail to grasp the significance of what IAS species do in ecosystems. To be sure, the changes that take place as invasive species become established are seldom dramatic initially, so people don't perceive the implications or appreciate the full consequences until it is too late. Efforts to educate the public about the distinction between native species and introduced, non-native ones have so far been inadequate to non-existent.

The gradual decline in general science knowledge has been coupled with an increasing cynicism toward government. Political scandals have imbued many with a disdain for government and elected officials, based on a deep-seated scepticism. In some cases, people simply no longer believe that the government is telling the truth and this applies to invasive species issues as it does to other aspects of daily life. Other factors are an anti-science attitude that has become more apparent in recent years, and even an attitude that can best be described as apathy or indifference on the part of some informed individuals who know enough to understand the issues surrounding IAS but simply do not care. In extreme cases, even when overwhelming evidence is available, some people still refuse to accept that IAS are a problem, even going so far as to come up with alternative explanations and views of reality. Such cases are, fortunately, a small minority. Readily available access to communication media, however, can lend them a disproportionately large presence. Cynicism toward government and lack of understanding of the problems caused by IAS are undoubtedly crucial factors involved in the lack of cooperation by the public.

Human dimensions in management and regulatory efforts/programmes

That there is a culture associated with sciences is now recognized and there is also a culture that is very much a part of regulatory agencies and management processes. Human dimensions here affect how IAS issues are addressed. Among germane considerations are concerns about how IAS are targeted for containment and eradication efforts. Is sound science behind the decision making, or do personal prejudices, funding allocations, and political agendas influence which species are targeted?

It seems that management efforts can become focused on high-profile species (e.g., "sexy species," frequently made so by the power of media attention). Once these command attention,

resources are poured into programmes targeting them. But are these media-driven efforts making the best use of the limited resources available?

It is also clear that many individuals involved in regulatory and management efforts have a strong emotional involvement in their work. Science strives for objectivity, dispassionate consideration of the facts, and rational decision making based on the facts. Management decisions based on solid scientific input are highly desirable, yet the loudest voice, the most insistent tone, and a persistently assertive presence often carry the day when such decisions are actually being made.

At a higher organizational level government agencies can be slow to respond to IAS issues, burdened as they often are by bureaucratic inertia and compartmentalized, rigid interpretations of programmatic responsibility and job duties. What type of entity, within human enterprise, could be most effective in addressing IAS issues? The complex and multi-tiered problems posed by IAS do not conveniently fit into existing organizational hierarchies, crossing as they do so many boundaries and affecting so many human activities and biological systems.

Reasons to be optimistic

While much needs changing if IAS problems are to be addressed in meaningful and productive ways, human attitudes and behaviour have already begun to change. Scientists have begun to discuss the re-integration of humans back into nature, rather than seeing humans as separate from nature (Mabberley, 1999; Bradshaw and Bekoff, 2000), and to call for a holistic approach to scientific study that offers a counterpoint to the reductionist thinking that has held sway for much of the last century (Bekoff, 2000). Even the very language used to describe science, the natural world, and where humanity stands in relation to both has been called into question (Stott, 1998, cited in Mabberley, 1999).

On a more immediate and practical level, dialogue has begun to an unprecedented degree between scientists (ethnobotanists, ecologists, anthropologists), indigenous cultural practitioners and knowledge bearers from diverse cultures, educators, lawyers, government and NGO officials, students, and anyone concerned about the transmission of information by both Western and traditional means. The second "Building Bridges with Traditional Knowledge" conference will take place in Honolulu, Hawaii, in May-June 2001. The sharing of different perspectives between such diverse groups of people from all parts of the world offers a bridge-building opportunity that affords another platform and context in which IAS issues can be discussed.

From another plane has come a resurgence of interest in growing native plants in many parts of the world, a renewed commitment to the biodiversity indigenous to a place in preference to alien species introduced from elsewhere. Plant breeders and gardeners have recognized that something precious and irreplaceable was being lost as super strains of crop plants quickly took the place of heirloom varieties; the development of informal seed-saving and distribution programmes, quite apart from existing agricultural seed banks and other germplasm collections, is a sign of interest in and commitment to maintaining genetic diversity for domesticated plants. In the world of tropical fish and exotic pets, more and more species are being bred in captivity, thereby reducing the demand for wild-collected stocks to be captured and translocated.

Not least among the bright spots is the appearance of several new books devoted to IAS and written for the general public (Cox, 1999; Bright, 1998). Particularly encouraging and welcome is the lengthy and detailed suggestions for action to be taken offered by Bright (1998). Fully one third of the book comprises an action plan for what individuals can do to deal effectively with IAS in their area.

All these activities, and many others like them, though small in the face of the monolithic structures and organizations that face them, are signs that awareness is growing and people do

care about the environment. It is to be hoped that with education about IAS this awareness and concern can be directed into constructive action.

Conclusions

If we are to slow the spread of invasive species around the globe then we must find means to redirect the processes that cause humans to spread them in the first place. The conservation movement must make effective use of communications technology to educate people about the nature and extent of the problems caused as well as their own role in the processes that spread species outside their natural range. Technology must be harnessed to find effective ways to prevent unintentional spread of alien weeds and pests through transportation and commerce. Most important, we must find ways to motivate people to learn about and take action on these issues. Apathy, scepticism, and ignorance are powerful opponents to overcome. The most effective approach is to encourage buy-in by other parties affected by IAS problems, such as human health, domestic animal health, commerce, and agriculture. The human bond with other species seems ubiquitous, but responses to the challenge of how to satisfy what appears to be an innate need are elusive.

To further clarify the deeper role of the human dimension in the IAS problem, scientists not yet involved in the IAS dialogue (particularly, social scientists, ethologists, psychologists, anthropologists) need to be engaged to ascertain what is known scientifically about the ubiquitous human affinity for other species. Is biophilia an innate behaviour? Is it a conditioned response? Can the human behaviour that stems from this attraction to other species be modified and redirected? If so, how? Success in controlling the spread and future introductions of IAS may be dependent on what can be discovered about the underlying causes for human choice.

Perhaps it is time, and enough data are now at hand, to undertake a predictive modelling exercise to project what might be the outcome if we are unable to slow or stop the spread of IAS. Although many negative impacts of IAS have been documented on a case-by-case basis, what might the future look like if all these impacts continued, unabated? Although dire predictions are often uttered regarding the negative impacts of IAS, especially concerning a catastrophic loss in biodiversity, this has not so far been quantified over a span of decades, centuries, or millennia. What might be the short-term ecological consequences and the longer term evolutionary consequences if the world-wide spread of IAS continues? Evolution is often assumed to operate at a glacially slow pace, yet evidence has accumulated that some species of insects can adapt sufficiently over a rather small number of generations that the progeny appear to belong to a different species from the ancestor. Do we truly know what the outcome of homogenization of the world's biota will be? While there is an undeniable initial drop in species diversity, what would happen next? How long might it take for evolution to rectify such a colossal blunder by the most ecologically aggressive species on earth? Having a projection in hand could be useful leverage in trying to persuade those who are uninformed or misinformed about the seriousness of the problem.

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Planning Future Responses

Human dimensions of invasive alien species in philosophical perspective: towards an ethic of conceptual responsibility

Johan Hattingh

Abstract

How can we find an appropriate language in which to formulate our concerns about, and our policy responses to, the problem of invasive alien species? This question arises from the tensions between our conventional vocabulary and the context within which we have to use this vocabulary. Characterized by both globalization and the so-called postmodern condition, this context confronts us on the one hand with the homogenizing effects of the dominant ideology of advanced industrial societies and on the other hand with a loss of faith in the grand narratives of modernity. The contours of these features of our contemporary world show that the grand narrative of universal progress for all, guaranteed by scientific management, can be confronted by numerous localized narratives within which we can articulate alternative notions of self, other, time, history, origin, community, and what it means to be a good member of the community. The conceptual distinctions we make about invasive alien species are closely linked to value choices, and both these conceptual distinctions and value choices are made and legitimized within narrative frameworks. In terms of these observations I plead for an ethic of conceptual responsibility in which we self-consciously and self-critically locate ourselves within the narratives we use in our discourse about invasive alien species, and take responsibility for the distinctions and value choices we legitimize from within the framework of these narratives.

Introduction

Within a philosophical framework, the human dimensions of invasive alien species (IAS) can be explored from different perspectives. One obvious point of departure is to consider the *concept* of IAS and to highlight the difficulties we face when we try to delineate clearly what exactly we mean when we refer to a species as alien and invasive. Another obvious point of entry is to consider the *ethics* of IAS, i.e., the different and often clashing values invoked when we express concern about and formulate policy responses to IAS. Both of these perspectives, however, need to be expressed in an *appropriate language* about IAS that can articulate our concepts and values in ways that can be heard by those we are seeking to influence. This linguistic framework, together with its assumptions, implications and consequences, is usually taken for granted and very seldom critically scrutinized.

This paper focuses on the question of finding an appropriate language with which we can articulate our concerns and formulate our policies about IAS. This level of analysis will reveal several significant human dimensions of the problem of IAS, illuminating usually-ignored

assumptions about ourselves and our relation to non-human animals and plants. This focus on language also makes it possible to clarify the conceptual and value dimensions of IAS in ways that would not be possible otherwise.

The question of an appropriate language to speak about IAS arises at least partly from the apparent tension between our conventional vocabulary about IAS and the context within which this vocabulary is used. On the one hand, our vocabulary about IAS is informed by conceptual oppositions like native-alien, indigenous-exotic, pure-contaminated, pristine-disrupted, stable-unstable, resilient-degenerative, healthy-unhealthy, harmless-harmful, diversity-homogeneity, natural-artificial (introduced by humans), original-degraded, normal-abnormal, etc. Ideals like purity, essential characteristics, ecological integrity and authenticity associated with these oppositions, however, are undermined by the highly ambiguous context within which we currently live, characterized as it is by the forces of globalization on the one hand and the so-called condition of postmodernity on the other.

Following the introduction of alien species throughout the world for centuries, but particularly in colonial times, travel and trade in the virtually borderless world of the global village can be seen as one of the major contributing factors to the problem of IAS today (e.g., Low, this volume). At the same time, the solution to the problem of IAS cannot come from within globalization itself. With its tendency towards homogenization, globalization is unable to provide us with a conceptual framework that is sufficiently strong and can adequately support the concepts – like uniqueness, ecological integrity and biological diversity – that are required to adequately delineate and appropriately respond to the problem of IAS.

For reasons that I will discuss below, we will have to look beyond the assumptions informing globalization for a framework from which the problem of IAS can be articulated and addressed sufficiently. But in this regard we are faced with the challenges of the condition of postmodernity in which the very notions of uniqueness, authenticity, and integrity have been undermined. Instead, ideas like hybridity and openness towards the reality of the other prevail, placing uniqueness, authenticity and integrity if not within the frame of nativism, then at least in that of xenophobia – both of which are the "political" correlates of what can be portrayed as biological essentialism.

The question then is whether it is possible to find a language with which to speak about IAS that goes beyond mere subservience to globalization and its homogenizing forces, and at the same time escape the forms of essentialism, purism, xenophobia and nativism that postmodernity warns us about, as well as provide a workable platform on the basis of which effective policy responses to the problem of IAS can be formulated. In order to address this question, we first need a perspective on globalization that can help us to understand "the inner logic" informing its tendency towards homogenization, explore what the implications of this inner logic are for our understanding of the problem of IAS, and suggest how this inner logic might be overcome. This will be done in Section 2, where globalization is discussed from a critical philosophical perspective.

Second, a brief characterization of our postmodern condition is required in order to form a better understanding of the forms of rationality and political action available to us today. This will be done in Section 3 in terms of a breakdown of belief in grand narratives and the de-naturing of our lives that this involves. Emphasis will also be placed on the notion of the narrative justification of our knowledge and actions. Section 4 will briefly discuss several implications of these considerations for the concept and ethics of IAS. For reasons presented in that section, Section 5 will argue that we must explicate and critically assess the narrative frameworks within which we locate our discourse about the problem of IAS if we would like to generate an effective response. The concluding section will highlight several practical implications for policy debate about IAS.

Globalization in critical perspective

Globalization can be seen to represent an integration of the world made possible by the spread of capitalism, Western imperialism and the development of a global media system (Robertson, 1990; Gare, 1995). According to Gare (1995: 6), it is "associated with new forms of media, new forms of technology and new forms of management which have transformed the spatio-temporal relations within capitalism". Within this unity, time and space have acquired new meanings. The ease with which communication can take place over vast distances, and the speed with which people and goods can be moved from one part of the globe to another, has undermined our conceptions of time and space as barriers that are difficult for people to overcome.

In institutional terms globalization entails the rise of transnational corporations, international financing, and multi-media marketing in close interaction with one another as the three main power houses of the new global economic system. In conjunction with one another, these institutions not only outstrip the political power of most of the nations, but also can effectively take control of national economies. This represents a shift in the balance of power, decentering the cultural, economic and political significance of the "core nations" of the recent past (Europe and North America), but at the same time undermining and destabilizing the identities of the so-called growth nations or emerging markets of the world that are newly incorporated within the world's economic system.

This has been made possible by the rise of a new international bourgeoisie (Gare, 1995), a set of managers, bankers and marketing specialists who are professionally trained to sustain the world's economic system. Dependent as the world economy has become on ever faster and more efficient electronic communication, this breed of "symbolic analysts" has to a large extent been transformed into information processing cyborgs with little or no allegiance to any national identities.

The ideology underlying this process of globalization has been characterized by Arran Gare as post-Keynesian neo-classical economics. He succinctly elaborates that this entails:

> … not only monetarism, rational expectations theory and supply-side economics, the ideological weapons of the new right in their struggle to dismantle social welfare provisions and institutions and to promote the deregulation of markets and reduction of trade barriers, but also by the rapid expansion of econometrics and computer modeling, and the transformation of economics from a science primarily concerned with guiding political policy-making to a science concerned to guide investment decisions by financiers (Gare, 1995: 11).

"Normal" and self-evident as this ideology may sound to many, it can be questioned on a number of important philosophical points. First, the economic rationality of globalization is embedded within a grand narrative of universal progress for mankind through scientific management that in itself is far from self-evident. This grand narrative, with its emphasis on scientific-technological control and mathemetic certainty, emerged from the ideals of the seventeenth century Enlightenment in Europe. It entails a drastic narrowing down of a wide humanistic perspective in which particularity and diversity are important to a perspective that is predominantly mechanistic in nature, and reduces the value of everything to its instrumental value as an available resource that is accessible and manipulable on demand (cf. Toulmin, 1990).

Second, the new bourgeoisie of the global economy sincerely believe that they have realized the goals of the Enlightenment, and therefore the West's grand narrative of progress for all. Fukuyama (1992), for instance, has captured this belief with his pronouncement that the history of the world has now come to an end. With such a framework of the end of history, it seems as if all sense of direction is lost. Gare (1995) points out that "[f]or the new bourgeoisie there is

nothing but power for the sake of power, control for the sake of control, and conspicuous consumption on a massive scale". What is lacking in this picture, however, is a self-critical awareness that the model of progress and development that is envisaged here is that of a particular, historical class of people; it has never represented the universal ideals of humankind. This picture also does not recognize that instead of progress and development for all, globalization has brought instability and uncertainty on many levels, if not starvation and death, to millions of people. The environmental correlate of this is technologically marked, degraded and fragmented landscapes, exploited to serve as the resource bases of ever-increasing demands of global production and consumption.

These observations have numerous and far-reaching implications for our discourse about the problem of IAS. An important one is that from within the dominant ideology of globalization, concern about IAS can only be "registered", that is, taken seriously, if it threatens the resource base of the world's global economic system. Accordingly, the problem of IAS will only be addressed if it makes economic sense to do so. Given the prevalent economic rationality of globalization, this means that threats from alien invasives to resources or the environment that cannot be translated into significant monetary figures will have no hope of ever being addressed. Within the economic rationality of globalization, money, or figures – that which can be quantified – will always win, and aesthetic, recreational, cultural and spiritual values that cannot be translated into monetary terms will always lose out.

On one level, this raises the question whether this kind of economic rationality should be allowed to prevail, or whether we should make peace with the fact that this is the way the world is currently going, and that we have nothing else to bring to the debate than numbers. On another level this quandary confronts us with the question of whether we should try to make adjustments to our practices within the grand narrative of universal progress through scientific management, or whether it is time to reconsider this whole grand narrative. Some pointers to an answer to these questions are highlighted in the discussion of post-modernity in the next section.

Postmodernity and the de-naturing of our lives

In one of the most influential diagnoses of contemporary culture, Jean-Francois Lyotard (1984) characterized the postmodern condition as a breakdown of faith in grand narratives. As he sees it, humankind has legitimized its knowledge as well as its actions since time immemorial in terms of narratives. What counts as (scientific) truth and what counts as ethical or just action are both authorized, Lyotard maintains, in a particular time by certain narrative structures in society. In fact, society itself is constructed through narratives: the social bond, i.e., what counts as society and meaningful interaction, is constructed by narratives which can be conceived of as language games. Given the phenomenon of competition between narratives, and the fact that certain narratives can dominate others, Lyotard (1984) introduces the principle of *agonistics*. Derived from *agon*, the Greek word for contest or battle, but also for pain, the principle of agonistics indicates that the borderlines and acceptance of a particular narrative is defended through the pain of struggle, through strategic moves and countermoves reminiscent of military battle. This does not prevent new narratives from becoming established, but this will only be possible through the painful process of battle, disrupting the dominant narrative from the point of view of an alternative "logic", and then slowly and agonizingly winning support for it through a long process of persuasion. He thus contends that it is much more difficult to establish a new narrative/language game than to merely suggest a new move within an existing one.

Turning to the legitimization of knowledge in advanced industrial societies, Lyotard points out that since the nineteenth century, Western culture has been characterized by two rival narratives of knowledge and society. In one story, society forms an organic whole, like a living

organism. During the 20th century, with the emergence of cybernetics, this image has been expanded so as to portray society as a self-regulating system. Within this narrative, the stability and the optimum functioning of the system is of paramount importance, thereby establishing *performance*, guaranteed by science, as the highest value. Accordingly, knowledge and action are justified in so far as they contribute towards the practical ideal of the optimum functioning, integration or maintenance of society. They are deemed dysfunctional insofar as they distract from these values.

A rival story opposes this technocratic narrative of systemic self-regulation. Stripped to its essence, this alternative narrative maintains that society is divided in two. According to the Marxist version of this story, class struggle and dialectics ensure progress in society. Formulated in general terms, this story line maintains that a duality is operating in society. Resisting incorporation within the unitary and totalizing practices of the system's managers, it draws our attention to critical theory, struggle and the ideal of emancipation. Accordingly, knowledge and action are justified in so far as they contribute towards the formulation and establishment of alternatives to the (capitalist) system. From a historical point of view, however, it is clear that this critical model has not only lost its political credibility during the course of the twentieth century, but also its theoretical standing, thereby marginalizing it to the status of "utopia" or "hope", with symbolic action (tokenism) as perhaps the only form of protest against the system that is still open to it (Lyotard, 1984).

Lyotard sees both of these stories as grand narratives. The first one constitutes the grand narrative of systematicity that dominates our world to a very large extent today, while the second one constitutes the grand narrative of emancipation. These could be seen as two versions of the meta-narrative of universal human progress through science and rationality. By a grand narrative Lyotard means a story in which an all-encompassing vision of history and society is articulated under the pretension that it portrays the whole and the only truth about it. As such, grand narratives are metaphysical in nature, assuming the existence of an original or foundational truth behind empirical reality from which everything is derived, or towards which everything is developing.

A grand narrative, therefore, is exclusivist, totalizing and authoritarian in its functioning, exerting a kind of violence in so far as it establishes itself as the only possible framework from which to operate.

However, Lyotard characterizes the postmodern condition by a loss of faith in all of these grand narratives. The grand narratives of systematic control, emancipation and universal progress are in crisis. They have lost credibility for postmodern society; they are no longer able to provide us with credible justifications for our knowledge and action. We are instead confronted with a situation in which these grand narratives function at best to provide us with illusions of systematic control, security, efficiency, freedom and progress. What we find in their place are scores of fragmented or localized narratives (micro-narratives if you will) vying against one another for our attention. Bauman (1992) has pointed out that the political correlate of this phenomenon can be found in small groupings of people that are not necessarily united by a shared physical locale, but rather by a shared cause, or concern about a particular issue. Accordingly, contemporary politics has tended to become increasingly oriented towards symbolic action by a small number of highly organized "activists" in order to gain public support for particular responses to specific issues.

This tendency is borne out by various developments in contemporary linguistic and cultural theory in which it is pointed out that all of our fixed points of reference have become fluid, and that our lives have become "de-natured" (cf. Gare, 1995; Hayles, 1990; Jameson, 1991). Language, for instance, no longer functions as a transparent mirror of a reality perceived as objectively there, but rather serves as an opaque medium through which we construct that which counts for us as reality (Baudrillard, 1992). Similarly, the notion of context that has been used in the past to establish a sphere of shared experiences and thereby narrow down

interpretations has been shattered. Instead we are faced with decontextualized information, in particular through the electronic media, leaving us with the disorienting experience that there is no single or universal context with clearly defined borderlines within which we can appeal to reason to settle our differences, but rather a multiplicity of mini-contexts that are not universally shared within which numerous incommensurable interpretations co-exist alongside one another (Benjamin, 1969).

The same applies to our notions of space and time (Harvey, 1989). The notions of natural space and time as the horizons within which we exist have lost their meaning. As functionaries within the economic system of today, we increasingly have to be on the move from place to place, living at a speed that seriously compromises our ability to retain history let alone develop a memory or a clear vision of the future. Similarly, our notions of origin and originality have become fluid. We know for instance that everything around us must have had a historical beginning, but as soon as we try to locate that within a particular place and time, these beginnings shift back indefinitely in time, leaving us at best in a state of spacio-temporal disorientation with no background against which things can be interpreted. We are also left with the experience that nothing is original any more but rather the copies of copies of things that have already been copied before (Derrida, 1988a).

These trends also have far-reaching implications for our notions of self-identity and a stable subjectivity. As Gare (1995: 30) has summarized it: "There is an absence in people of a sense of personal history, of a sense of their lives as unfinished stories worth struggling to complete, integrated into the stories of their families, their communities, the organizations within which they work and their society. Such an absence goes to the heart of modern culture, since it involves the dissolution of what since the seventeenth century it meant to be a person".

Under one interpretation of the postmodern condition, the implications of this characterization for the debate about IAS lie in the fact that many of the notions central to the debate – like sense of place, sense of history, naturalness, authenticity, essence, health and truth – seem to be luxuries of a bygone era. This includes the conceptual opposition between native versus alien species. For some commentators working under this interpretation, the latter opposition reflects an essentialism, the defense of some kind of final (biological) truth residing in native species, and this, they would argue, clearly cannot be justified anymore – unless a nativist or an eco-facist stance is adopted (cf. Hudson, 1997).

This interpretation of postmodernity, however, leaves us with no justification to oppose environmental destruction or degradation. In fact, it paralyzes us to a point where we have little or no grounds to even make a distinction between native and alien species, let alone distinguish between harmless and harmful species. This clearly takes the debate about IAS to untenable extremes, leaving us with nothing but a sense of resignation about the landscapes and ecological systems we live in, no matter how degraded or "invaded" they are by alien species.

Under a more moderate interpretation of the postmodern condition, however, a different picture emerges. Taking into account that we indeed no longer have any grand narratives to legitimize our knowledge and our actions, and taking seriously the point that we do not have fixed points of reference to fall back upon in our debates, the resultant fluidity and uncertainty can be interpreted positively as an ethical challenge to make certain decisions, to put certain conceptual distinctions and certain policy decisions about IAS into practice, and to take the full responsibility for the foreseen and unforeseen consequences that this may entail in real-life terms (Culler, 1983; see also Derrida, 1988b). Acknowledging that the conceptual distinctions we use in our policy debates about IAS entail a measure of violence in so far as they are imposed on "reality" and insofar as they exclude or marginalize rival conceptual schemes, this responsibility also requires that we at least try to minimize the violence of our conceptual distinctions. This can be done by becoming self-conscious about them.

From this perspective, then, we need not discard all our conceptual oppositions – we instead must recognize their historical emergence within our vocabulary, and clarify the assumptions

on the basis of which we use and continue to use them, making sure that we can live with their implications and consequences. Instead of taking our conceptual distinctions for granted, we must acknowledge that they have a long history, that they are embedded within larger narrative structures, and through that, are strongly linked to other conceptual pairs, to such an extent that together they form a web of mutually supportive distinctions. Furthermore, we must acknowledge that this kind of conceptual web is never totally neutral; based on fundamental political and ethical choices, our conceptual distinctions have very concrete real life consequences. In terms of the IAS debate, these conceptual distinctions can lead us to choose and implement any of the classical policy options available to us, namely prevention of invasion, eradication when invasion has occurred, or containment and management when eradication is found to be impossible. Since it can be argued that these responses are violent in themselves, the ethic of conceptual responsibility delineated above places a duty on us to always explicate and critically assess the narrative frameworks within which we endeavour to justify this violence.

To formulate it differently: the conceptual web we use in our policy debates about IAS tells its own story. The conceptual distinctions we make in order to identify a "problem" of IAS are part of a narrative that we use to justify our knowledge about IAS as well as our actions (policy choices) with regards to them. From a critical philosophical perspective, we must acknowledge the narrative structure within which our arguments about IAS are embedded, and to ask whether everything is consistent with it. Formulated positively, the argument developed above confronts us with the question of whether we know within which narrative we operate when we debate the problem of IAS, and whether we can live with its assumptions, implications and consequences.

Conceptual and ethical implications

A narrative approach to the problem of IAS can help reveal aspects of the concept of IAS and the values invoked in policy debates about the problem that one would not have access to otherwise. As a point of departure for this illustration we can examine statements about the problem (or non-problem) of "invasive alien species" like the following:

1. Non-native plants constitute a significant threat to the integrity of Pennsylvania's native plant communities. The 1993 book*, The Vascular Flora of Pennsylvania: Annotated Checklist and Atlas*, lists 3,318 species of plants that grow in the state, of which 37% or 1,242 were not present before European settlement (Rhoads, 1997).
2. In certain parts of Australia, introduced plants or native plants spreading well beyond their natural range have destroyed whole ecosystems, with disastrous consequences for the indigenous inhabitants, as well as for the human population (Rawling, 1994).
3. Alien species may do well because they are freed from natural enemies, competitors, and parasites (cf. Lugo, 1994).
4. With reference to the human introduction of mountain goats in the Olympic Mountains in 1920, a certain Lyman " … challenged the idea that the National Park Service should view the goats as alien species. Lyman's arguments were based upon a speculative dispersal model for *Oreamnos* during the late Quaternary. Based on the model, mountain goats might have occupied the Olympic Mountains earlier in the Quaternary. He also speculated that mountain goats may have been present historically in unexplored areas of the mountains" (cf. Houston and Schreiner, 1995).

We can also take straightforward definitions like the following:

5. Alien species are those that occur in a given place as a result of direct or indirect, deliberate or accidental action by humans (not including deliberate reintroductions) (Houston and Schreiner, 1995).
6. Alien species (synonyms: non-native, non-indigenous, foreign, exotic): a species, subspecies, or lower taxon introduced outside its normal past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce (McNeely, 2000).

From citations like these it is evident that at least five conceptual criteria are commonly used in order to identify an IAS:

- The human introduction criterion
- The degradation criterion
- The historical or natural range criterion
- The evolutionary origin criterion
- The non-integration criterion

According to these criteria, an IAS would be one that:

- has not been introduced naturally, but by humans – albeit directly or indirectly, intentionally or unintentionally;
- has not evolved naturally in the area in which it has been introduced;
- lives outside its native range;
- has a degrading effect on native species in so far as it displaces them or "changes the nature, character, form and conditions" (Richardson *et al*., 2000) of native species; and
- exists outside an ecological community insofar as it has no natural dependence on members of the ecological community with which it co-exists, or is subject to no natural controls characteristic of that ecological community.

It should be borne in mind that the application of these criteria is far from simple and straightforward. For the purposes of this paper, however, it suffices to point out that any application of these conceptual criteria already presupposes a number of important value choices – and that we often do not acknowledge the fact that we do so, or confront ourselves with the question whether everything is consistent with the manner or the frameworks within which we make these value choices. The general point is that the difficulties we have in applying the concept of IAS can arguably be related to the uncertainties we experience when we are confronted with the value choices we have to make in our utilization of the concept. After all, each of the conceptual criteria listed above requires us to draw some kind of line, and it is not always clear where we should draw that line, why we should do so, and how we should go about justifying that "why".

These points can be conveniently illustrated with the hypothetical example of the human introduction of a plant species into a region sufficiently long ago for it to have significantly speciated – to such an extent that it no longer is identical to the species that was originally introduced. Having had no natural enemies in its new environment, it has started to displace native plant species, but although it is degrading the ecosystem into which it has been introduced, an endangered bird has become dependent on it for its survival. In this example the human introduction criterion is invoked, but it also draws our attention to problems that we may experience in applying other criteria, like that of evolutionary origin and historical cum natural range. Besides the preference given with the human introduction criterion to non-human or less-humanized ecosystems and the question of how this could be justified, we are also faced here with the problem of where to draw the line in time when distant ancestors of a species were introduced to an area, but since its introduction it has significantly speciated so as to become

something other than what was originally introduced. This example also questions our notions of area of origin, or historical range: how do we determine that?

From these initial questions it is already evident that we face not only conceptual problems when we have to identify alien species, but also value choices, the basis of which are not always clear. For example: the human introduction criterion requires us to make distinctions between non-humanized and less-humanized ecosystems existing independently of humans on the one hand, and humanized ecosystems on the other, dependent upon or the result of human action. The value of naturalness is introduced here, but this raises the question of the basis for the preference indicated in this value. The conceptual criterion of evolutionary origin also requires us to draw a line in the history of an evolving ecosystem and to identify the state in which that ecosystem was before that timeline as original, while its state after that time represents a deviation from that original state. At the same time it requires us to determine areas of origin inside of which species are native, and outside of which species are not. This introduces the values of originality and authenticity, again showing that the concept of alien species is not purely dependent upon objective ecological criteria, but on the kind of time-space demarcations we use to identify origin or authenticity. For a clear understanding of the problem of IAS and the arguments informing our policy responses to it, we are then obliged to also explore the "subjective" side of the equation – to explicate the basis for the conceptual as well as value distinctions we make in this regard.

Similarly, the conceptual criterion of historical or natural range requires us to demarcate in space and time a certain area of origin and what it means to be "inside" and "outside" of that area. And like the conceptual criterion of human introduction, this context requires us to determine the borderlines of natural and unnatural. The conceptual criterion of ecological degradation and membership of an ecological community raises similar problems. Even if we grant the fact that much highly valuable work has been done in invasion ecology to develop objective criteria to determine the kind and extent of ecological degradation brought about by alien species, it is still humans who introduce the value distinctions between healthy and unhealthy, between harmed and unharmed ecosystems, or between "good" and "bad" non-native species. In so far as harm and health and good and bad are anthropogenic concepts (after all, nature cannot articulate that it has been harmed, is healthy, is good or bad), our criteria to determine this beg the question as to the basis on which we make these value distinctions.

To apply the conceptual criterion of membership of an ecological community, we make value judgements regarding the extent to which a species has been *integrated* into an ecosystem. Applying this criterion therefore assumes that we have answered a number of other value questions. For example: what is an ecological community? What does it mean to be a member of an ecological community? What does it mean to be a good member of an ecological community? What does integration mean? Balance? Mutual dependence on other members of the ecological community? Subject to mutual controls exerted by the respective members of the ecological community?

Given the framework of the postmodern condition within which we live, and the substantive loss that we experience within this condition of fixed points of reference, it is clear that the seemingly simple task of applying a concept such as "IAS" becomes highly problematical. As we have argued, it is not only a matter of conceptual determinations that have to be clarified, but also a number of interrelated value choices. And on both levels, we do not have clear guidelines as to what we should choose. Yet, we cannot avoid making these choices. So where do we turn to for help in this regard?

An ethic of conceptual responsibility

From a moderate interpretation of our postmodern condition, "help" – if we want to call it that – is available from an ethic of conceptual responsibility in which narrative is taken seriously.

Within this ethic, it is acknowledged that we do not have absolute or objective points of reference in terms of which we can make our value choices about the recognition and our responses to IAS. We do, however, make and justify these choices within the framework of often unacknowledged localized narratives that we share with others about matters such as *ourselves* in contradistinction from *other humans* and other *non-human living entities*, *history*, *time*, *space*, *origin*, *health, community* and what it means to be a *good member* of a community. To the extent that we explicate and examine the narrative frameworks that we share with others, we are able to ask questions about the manner in which we make and justify our value choices. In terms of this approach, not to do so would be irresponsible.

An important feature of this ethic of conceptual responsibility is that it cannot step outside of narrative frameworks itself. It finds itself in the paradoxical position that every explication and examination of a narrative framework takes place within a narrative framework. As such this does not constitute a problem of vicious circularity. On the contrary, it is exactly what is emphasized within an ethic of conceptual responsibility: that we should acknowledge that numerous narrative frameworks are interacting with one another in policy debates about IAS, and that we should ask questions about and take responsibility for the assumptions, implications and consequences of the ones from which we choose to work.

In practical terms, this ethic of conceptual responsibility requires us to look out for, to explicate and to examine the dominant narratives currently in use in our debates about IAS. It requires us to delineate the contours of these narratives, the manner in which they function, their history, the mechanisms through which they have been established as authoritative and through which they are institutionalized and therefore perpetuated, as well as the practical policy and political consequences they lead to – and to ask ourselves whether we can live with that. At the same time it requires us to explore the possibilities of other or alternative narratives which might be able to better articulate our concerns about IAS and better justify our policy responses to this problem than can be done from the dominant current narratives.

Restrictions on the length of this paper prevent further development of this point, except to mention in passing that the economic rationality of our era of globalization provides the dominant narrative currently available to us to articulate our concerns about the problem of IAS and our policy responses to it. Given the kind of financial calculus characteristic of this rationality, as well as the concomitant forms of scientific management and marketing that it implies, the story told from within this framework about IAS is one of the costs of resource degradation or destruction, the appropriate policy response to which is then the most cost effective and efficient one to reduce these costs (see, for example, Perrings, Williamson and Dalmazzone, 2000). And given the predominance of marketing as a tool of legitimizing narration in our era of globalization, one would also expect marketing strategies specifically designed to raise public awareness of the problem and to engineer a positive attitude towards the measures taken.

If this is the way to go, an ethic of conceptual responsibility would require us to become aware of the assumptions, implications and consequences of this narrative framework, and then to ask ourselves whether the story it enables us to tell is the only one to tell, and whether it enables us to give an adequately complete picture of the problem of IAS as we experience it in real life terms. On a more radical level, however, an ethic of conceptual responsibility would also explore the possibilities not of merely making a new move within this already dominant narrative framework, but of asking whether the dominant framework of economic rationality is the only framework available to us, or whether other legitimate possibilities could serve as alternative narrative frameworks for us to use.

Conclusions

In the light of these considerations, I would like to argue with Gare (1995) that we need new narratives. In the wake of our loss of grand narratives we would know what to do only when we know in which stories we find ourselves a role. Given that it would be impossible, and arguably not even necessary, to restore faith in one, single, universal truth that is absolute and all-encompassing, it follows that these new narratives would have to be non-metaphysical in character. At the same time they would have to be non-teleological – in the sense that a view of history as the gradual unfolding of some essence through time is traded in for a view of history as a creative process of becoming in which there is no ultimate end or goal (Whitehead, 1969/1929; Cilliers, 1998). Accordingly, every step in this process, as well as every participant in it, becomes important. Indeed, we as humans choose what this process should look like and how to participate in it. The narratives we develop about this process and how to participate in it can therefore also not be a monologue – informed by one single "truth" – but should assume the character of a dialogue in which many factors and many considerations are allowed to speak on an equal basis. Since the different voices of these dialogical narratives are in real life situations to a very large extent in a constant battle with one another for supremacy, we should also include in our narratives story lines about power and how to recognize and resist efforts to turn dialogue into monologue, open debate into imposition.

As abstract as this may sound at first sight, these observations have far-reaching implications for our policy debates about IAS. In the first place, this narrative perspective makes it possible for us to acknowledge that things like a "sense of community", and in particular a "sense of an ecological community" are delineated *by us*. The border lines we draw around ourselves or around ecological communities in order to distinguish between that which is "native" and that which is "alien" are therefore in a sense "imaginary" (Gare, 1995) – they are constructed *by us*, by the stories we tell, and they only exist in so far as we choose to continue to tell these stories.

In the second place, this narrative perspective enables us to see that the well-known three-tiered policy response to the problem of IAS (namely prevention, eradication, and containment under heavy management if the first two did not succeed completely), hinges on the narratives we develop and share with one another about our selves and what is other, what is native and what is alien – to mention but two value-laden conceptual distinctions we make within this context.

This then calls for an ethic of conceptual responsibility – that is, an ethic in which we take responsibility for the conceptual distinctions we choose to make and the values we allow to inform these choices. This ethic of conceptual responsibility requires us to articulate as far as possible the reasons for our conceptual distinctions and the narrative frameworks, and the codes and the rules in terms of which we utilize them. It requires us to acknowledge that these narrative frameworks in terms of which we think and act have histories, are imbued with ideological bias, and have significant real life consequences. It also requires us to avoid final answers in our thinking as well as in our actions, to acknowledge that we cannot realize absolute truths or final certainties. Instead it cautions us, among many other things, to always act in such a manner that we can be corrected by the consequences of our actions (Schroten, 1990; Achterhuis, 1992).

I again concede that this may sound far removed from those clear-cut cases where it is blatantly obvious that significant damage has been caused to ecological communities by IAS. On face value it seems as if the above should only be applied to those borderline cases where it is not clear whether we are dealing with ecological or environmental harm, or where it is not evident that we are dealing with an IAS or not. On the other hand, though, to apply the perspectives developed above to central cases as well will enable us to look beyond our well-known problem formulations and policy responses. It may help us to consider more than the conventional criteria to differentiate IAS from natives; to consider more than the conventional

values to explain why IAS are bad. It may help us to become aware of the fact that we can develop new story lines and new chapters to the narratives we share with one another about the problem of IAS and our policy responses to it.

Acknowledgements

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Scenario planning: understanding and managing biological invasions in South Africa

R. Arthur Chapman, David C. Le Maitre, and David M. Richardson

It was ordained at the beginning of the world that certain signs should prefigure certain events

Cicero

Abstract

Scenario planning is a useful technique for dealing with complex issues such as biological invasions in natural ecosystems. Invasions are driven by four primary driving forces: arrival and accumulation of propagules (seeds, spores, whole organisms and vegetative parts); disturbance regimes; fragmentation of natural landscapes; and changes in the availability of limiting factors. The primary driving forces are influenced by a range of secondary driving forces which are mediated by people. Some of these forces can either facilitate or constrain invasions depending on circumstances but the direction in which they will act is not known. These are termed uncertainties and their future trajectories will shape the future of invasions. A scenario analysis prepared for South Africa showed clearly that gaining the political support to implement coherent policies, laws and regulations is one of the most important ways in which the biological invasions can be controlled. The ability to do this will depend significantly on the availability of the necessary resources which, in turn, depends very largely on sustained economic growth and the support of the general populace.

Introduction

Biological invasions are generating increasing concern worldwide as awareness of the extent of their often irreversible impacts, and the difficulties of implementing effective control measures, increases. In common with many other countries, the natural environments in South Africa have been invaded by a wide variety of introduced plant and animal species (Richardson *et al*., submitted). The most conspicuous and best documented group of invaders are woody plants which have invaded and transformed, to some extent, roughly 10 million hectares (8%) of the country (Versfeld *et al*., 1998). They have a significant, but poorly documented, impact on biodiversity (van Wilgen *et al*., 1996) and currently waste about 3,300 million cubic metres each year – 7% of South Africa's annual runoff (Versfeld *et al*., 1998). The invaded area is expanding at a rate of perhaps 5% per year, leading to a doubling of invaded area, and of the

impact on water resources, every 15 years. This is a critical issue for a country that has limited and unevenly distributed water resources and whose economic growth is already constrained by water shortages. In this paper we have focused on invasive woody plants because they are the best documented and their invasion ecology is relatively well understood (Richardson *et al*., submitted). Although the focus is on a limited group of invaders, the processes and forces which we analyse are applicable to all biological invaders.

As a nation, we need to anticipate and understand the possible trajectories of invasions through time if we are to take decisions now that will result in the best possible outcome in the future. We cannot achieve this by concentrating only on the biology of invaders. We cannot understand the intricate interactions that lead to invasions only by modelling. We need to address this in an all-inclusive manner which takes into account: (a) the extraordinary complexity of the human enterprises and human-dominated systems; (b) the ways in which these systems facilitate and hinder invasions; and (c) yet provides a logical and tractable approach to identifying and understanding the main factors that drive invasions. Scenario planning is a tool that can be used to achieve this and, at the same time, present the results in a way that is comprehensible to the general populace. We begin with some brief background on scenario planning and then illustrate the steps involved in developing scenarios using invasions by woody plants in South Africa as an example.

Scenario planning and the problem of invasive alien species

Scenarios are stories of the future that are plausible and are meaningful to their intended audiences. They help explain why things happen in a certain way and offer multiple perspectives on a complex problem. Scenario planning has roots in the Second World War where it was used to develop new tactics for the military. The methodology later became prominent when the Royal Dutch/Shell oil company used the technique to successfully communicate the likelihood of an oil shortage and to anticipate the 1973 "Oil Shock" (Leemhuis, 1985; Wack, 1985; De Geus, 1988; Kahane, 1992).

A well-known South African use of scenarios is the "*High Road"* and "*Low Road"* scenarios developed by Sunter (1987). These names have now passed into everyday language of a significant portion of people concerned with high-level decision-making. They enabled many people in South Africa to see a range of possible futures for the country and themselves, and allowed them to develop alternate views about what was needed to avoid a descent into economic and social chaos (Esterhuyse, 1992). The High Road and Low Road scenarios were extended to address possible environmental trajectories by Huntley *et al.* (1989). The resulting scenarios emphasized the inter-connectedness of the economic and social dimensions with the environment. A strong socio-economic trajectory, in conjunction with a strong environmental management ethic plausibly results in a sustainable future, while a weak environmental management ethic invariably results in unsustainability.

As a result of the Shell success story, scenario planning has become a technique for anticipating major shifts in the business environment (Wilkinson, 1995). It differs from forecasting because the emphasis is on highlighting and understanding the effects of the large-scale forces that push the future in different directions rather than the details of that future (Wilkinson, 1995). The range of possible future worlds described in a set of scenarios is thus defined by the outcomes of the important elements at work now that could create those worlds.

The key strength of successful scenario planning is the ability to deal with uncertainty explicitly. Invasion is a process that is inherently uncertain – it is very difficult to predict which species will invade, when and how fast they will invade, and what and how severe the impacts will be. Invasions are also often characterised by lag periods followed by very rapid increases

in extent, a result of adaption, or the impacts of infrequent events (e.g. high rainfall years). They can be described as *"long fuse-big bang problems"* (a term applied to general business problems by Wack, 1985), or as *"quiet opportunists, spreading in a slow motion explosion"* (USDOI, 1998).

Building scenarios for the South African situation

The Scenario Development Process

Scenario planning is a systematic procedure with recognisable phases or steps which follow a logical sequence (Box 1). It is not, however, a straightforward, mechanistic process, but rather one of iteration and approximation with many points at which critical assessments need to be made. We found this process worked well for us because as natural scientists it took a while to adapt our thinking to what often seemed to be a lengthy process.

Every set of scenarios needs to be built around a focal issue, a critical concern or uncertainty in the medium to long-term future. This issue is the real reason why the scenarios are being developed in the first place. It is useful to phrase the focal issue as a question, so in workshop mode we developed the following focal question for our scenarios:

What will the state of invasion by alien woody plants in South African catchments be in 20–30 years from now?

It is clear that there are no simple answers to this question, and that a range of forces, processes and factors could determine the answer. The next steps are to identify the driving forces, classify them, and determine whether their actions promote, retard or reverse invasions. The following logical series of steps to follow in developing a set of scenarios is taken from Shwarz, 1991, and Wilkinson, 1995:

1. Identify the focal issue (found by agreement and through consultation with relevant parties).
2. Identify the primary "driving forces" at work. (*Look past the everyday crises that typically occupy our minds and examine the long term forces that work well outside our concerns*).
3. Identify the predetermined driving forces, i.e. those that are completely outside our control and will play out in any story we tell about the future.
4. The remaining driving forces comprise the uncertainties, the things whose effect on the future (positive or negative) is unpredictable. Test each one to determine which ones are critical to the focal issue – these are the key uncertainties.
5. Reduce key uncertainties to groups that have a common thread or cause to a single spectrum, or axis of uncertainty (negative positive). One way to simplify the groups of uncertainties is to form two major axes of uncertainties by identifying things that are independently uncertain. Arrange the two axes at right angles (with the intersection at the midpoint) to form a four-quadrant matrix. Each of the quadrants should now define a plausible and distinct group which describes a possible future or scenario.
6. Flesh out the scenarios to make a "story" using the list of driving forces generated earlier as "characters". The goal is not to tell four stories, one of which might be true, because the "real" future will not be any of the four scenarios although it will contain elements of all the scenarios. The corners of the matrix are exaggerated – the outer limits of what is plausible – a near caricature quality.
7. Explore the implications of the scenarios and identify courses of action that will make sense across all of the futures. Those that make sense in all four scenarios are the decisions that should be implemented today. Work can proceed on the basis of these

decisions, in the confidence that they are more or less likely to play out. Some will make sense across only one or two; these require more care. Attempt to identify "early warning signals", for example by tracking trends or shifts in the driving forces, that tell us that those particular scenarios are beginning to unfold.

Identification of the Primary Driving Forces

The process of invasion is complex but the main influences come from just four driving forces:

1. the arrival of propagules and accumulation of propagule banks;
2. disturbance (particularly changes in disturbance regimes);
3. fragmentation of the landscape; and
4. changes in the availability of factors that limit invasions.

The direction and strength of action of these four driving forces is strongly influenced by human beings and their activities and enterprises such as trade, land transformation for agriculture, commercial forestry and potentially by global climate change, which itself involves some important uncertainties (see reviews in Mooney and Hobs, 2000). The activities of these enterprises, in turn, are affected by economic trends (national and international), population growth (local and regional), political systems and institutions, and legislation (local and international). Clearly, the driving forces and the factors that influence them operate on different scales (from local to national) and there are many links and feedbacks (positive and negative) between them. In scenario terminology, these four primary driving forces are essentially "predetermined" driving forces (see Box 1, Item 3). They are and will continue to be the primary forces driving invasions in whatever realistic future setting we can imagine.

Identification of the Secondary Driving Forces

Each of the primary driving forces, in turn, is influenced in various ways by what we call "*secondary*" driving forces, which operate from the local right up to the global scale. We listed a range of possible driving forces in a brainstorming session and found that they could be divided into two logical and natural groups: international forces operating outside South Africa and directed into the country; and forces operating inside South Africa (Fig. 1). There was some overlap but this distinction proved to be important later in understanding our ability, as a country, to influence those forces. These forces are not independent either, because they interact with others, both inside and outside South Africa, to have negative and positive impacts on the primary driving forces for invasions (Fig. 1). Each of the secondary driving forces is described briefly below and a more detailed description is given by Chapman *et al*. (in prep.). In what follows *I* denotes an international and *S* an internal (national) secondary driving force.

I1. Increasing human population and fluctuating migration patterns The more humans there are, and the more they move about, the greater the likelihood of them moving the propagules of biological invaders with them as they go.

I2. Expanding network of international trade and travel links The greater the number and variety of ways in which goods and people are moved, the greater the number of potential invasion pathways and introductions of new species.

I3. Increasing magnitude of international trade As the quantity of trade increases, the number of alien species or propagules landing in a country increases, increasing both the likelihood of an invader succeeding and its genetic diversity.

I4. Globalization of economies This process drives the relocation of industries, ostensibly based on lower production costs, but often simply exploiting the comparatively weak environmental legislation and awareness in developing countries.

I5. Global economic trends South Africa has a small and emerging economy which is highly vulnerable to international investment trends. The state of the economy and the way this determines the amount of money the government has at its disposal, in turn, determine the ability of the various authorities to implement measures to prevent, limit and control invasions in the face of other pressing needs that have to be addressed.

I6. Globalization of the forestry/agro-forestry enterprise The demand for increased productivity of forestry and agricultural enterprises is growing continuously, and these enterprises are planting an ever increasing area of invasive tree species. Land rehabilitation, while necessary, often involves using known invaders, but this risk is ignored because of the perceived benefits of the 'miracle' species. On the other hand, environmental certification provides a tool for control by requiring companies to limit the impacts of the invasive alien species they use if they wish to market products in many developed countries.

I7. Improved communication methods (internet, global databases) Modern communication technologies such as the Internet offer access to information on organisations promoting species, including known invaders, and provide ways of obtaining propagules. This trend may be countered by the growing number of global databases on problem species, many of which are being increasingly used to regulate and quarantine imports, and international e-mail networks for invasive species (e.g. the aliens-l list server maintained by IUCN).

I8. Growth and maturation of invasion ecology into a robust, predictive science Invasion ecology is still a growing science but it is already providing useful insights on which to base policies, laws and regulations, develop improved methods for screening species for invasive potential and new methods for controlling invading species.

I9. Global climate change Global climate change is likely to bring about significant changes in rainfall and temperature patterns in South Africa (and elsewhere in the world), as well more frequent and intense extreme events, such as droughts and floods. These changes are likely to facilitate invasions as natural ecosystems are placed under stress, disturbance regimes are altered and factors limiting invasions are altered or removed (for a review see Mooney and Hobbs, 2000).

I10. International treaties Numerous international conventions (e.g., Convention on Biological Diversity) aim, directly or indirectly, to reduce the magnitude of transfer of species between regions. South Africa has signed many of these conventions and is developing a Biosafety Protocol for genetically modified organisms. Other conventions and protocols (e.g. World Trade Organisation agreements) may promote invasions by promoting unfettered trade.

S1. Human population dynamics South Africa has an average population growth rate of about 2.4% which may be counterbalanced by the dramatic rate of increase in HIV/AIDS. The economic impacts of the HIV/AIDS will be significant and the associated social disruptions could affect lifestyles, particularly in rural areas. The impacts may include reduced use of invasive trees and shrubs as fuel and the abandonment of land. Both outcomes will facilitate invasions.

S2. Economic trends The economic performance of South Africa is heavily dependent on the global economy (I5) and world markets for raw materials (e.g. gold, platinum, iron) and exportable foodstuffs, as well as the local economy's efficiency, its balance and the standard of governance in the country. Sound economic performance provides scope for devoting resources to research and issues such as innovative and long-term measures of dealing with biological invasions (e.g. biological control) and for facilitating orderly land management. A poor economy on the other hand limits or excludes these options for intervention.

S3. Expanding infrastructure (road, rail and inter-basin transfers) The development of new infrastructure such as road and rail networks provides a mechanism for the transport and dispersal of propagules along new routes. The building of the infrastructure also provides new foci of disturbance during the construction. Seeds carried in soil by earth-moving equipment are a substantial source of invasion; inter-basin water transfer schemes also transfer aquatic organisms (both native and alien).

S4. Post-apartheid transformation (policy transformation) The government's land reform process involves a substantial movement of dispossessed people back onto the land, and increasing the numbers of black farmers. This process can either be orderly or chaotic, depending on the manner in which the government conducts its operations. A chaotic situation will hinder investment and farming methods are likely to be poor. This will promote invasions. Orderly land redistribution is likely to have the converse effect because "land care" practises are being encouraged. This will have a direct impact on the status of invasion as people understand the negative impact of aliens and therefore remove them.

S5. Changes in laws, policies and regulations South Africa is in the process of developing and implementing new policies, laws and regulations which will affect biological invasions, including a National Weeds Strategy. For example, some invasive alien plants may be declared a Stream Flow Reducing Activity under the new Water Act. This would require landowners to pay for the water wasted by invading alien plants on their land and would be an incentive for control.

S6. *Changing agricultural practices* Land development inevitably increases the fragmentation of the remaining natural ecosystems. The land reform process could promote this through subdivision of existing landholdings and by reallocating undeveloped State land for subsistence farmers. The more intensive use of the land may reduce invasions or facilitate invasions depending on the management practices. For example, use of fertilizers may alter nutrient regimes and encourage invasions.

S7. Options available for alien invader control Control is likely to be more effective when a greater variety of methods can be used. Two tools that can be developed further are biological control and screening and quarantining systems. The international networks of expertise on invaders provides a means of sharing and implementing these options much more rapidly.

S8. Fire Changes in land ownership patterns and use could lead to an increased or decreased frequency as well as altered seasonal patterns of fire, potentially facilitating invasions by fire adapted species.

S9. Afforestation (commercial forestry, agroforestry, social forestry) Plantation forestry often uses invasive species and plantations provide a habitat for many other invaders. The movement, in South Africa, towards contractors and small growers may facilitate invasions as these growers will lack the resources to control invasions and lack institutional structures for tackling the problem in a systematic manner. More woodlots and new locations for plantations also lead to more foci for the dispersal of propagules and more contact with natural ecosystems. These attributes favour the spread of invaders. The long residence times inherent in forestry may facilitate invasions by promoting species acclimatization and increasing the risk of an invader capitalizing on rare events that facilitate spread.

S10. Changing perspectives and paradigms in nature conservation The new and necessary trend towards increasing the involvement of local communities in the management of conservation areas may facilitate invasions as these areas become more open to the movement of propagules.

S11. Horticulture The increasing demand for invasive species for horticulture provides a ready mechanism for the spread of potential invaders. These species often bypass normal

controls at such places as air and sea ports. Increasing tourism and trade therefore may allow more propagules and new species to enter the country.

S12. Changing perspectives regarding alien species As the impacts of alien species become more evident and are publicized, so the attitude of people towards alien species is changing. In some quarters a "culture of non-tolerance" is developing, and institutional approaches such as Working for Water are having an impact on the problem. Nevertheless, some people take the alternative viewpoint and see alien invaders as valuable additions to our biodiversity.

Table 1 A matrix summarising the interactions between the driving forces.

	I1	*I2*	*I3*	*I4*	*I5*	*I6*	*I7*	*I8*	*I9*	*I10*	*S1*	*S2*	*S3*	*S4*	*S5*	*S6*	*S7*	*S8*	*S9*	*S10*	*S11*	*S12*
I1	1	3	3	2	2	1	0	0	3	2	3	2	2	0	1	2	0	0	2	1	0	0
I2	++	3	3	3	3	2	3	3	0	2	0	1	2	0	1	2	1	0	2	0	3	3
I3	++	++	3	3	3	3	3	3	2	3	2	3	3	1	3	3	1	0	3	1	3	1
I4	++	++	++	2	3	3	3	1	1	3	2	3	2	1	3	3	0	1	3	0	3	1
I5	++	++	++	?	1	3	2	2	2	2	2	3	3	1	1	3	0	0	3	1	3	1
I6	++	++	++	+++	++	3	3	2	2	3	0	2	2	2	2	3	3	1	3	2	0	3
I7	++	++	++		?	++	2	3	0	1	0	0	0	0	1	2	3	0	2	1	3	3
I8							–	2	3	3	0	0	0	0	3	3	3	2	3	3	3	3
I9	++	++	++	+++	++	++	++	++	2	3	3	3	0	0	1	3	2	3	3	3	1	3
I10								–	++	1	0	1	0	2	3	3	2	0	3	3	2	3
S1	++	++	++	++	++	+++	++	++	++		2	3	3	3	3	3	0	3	3	3	3	3
S2	++	++	++		?	++	++		++		++	3	3	3	3	3	3	3	3	2	2	2
S3	++	++	++	++	++	+++	0		++		++	++	3	3	1	3	2	3	3	1	2	0
S4	++	++	++	+	+	++	?		++		++	++	++	2	3	3	1	2	3	3	1	2
S5								–							2	3	3	1	3	3	2	3
S6	++	++	++	++	?	++	++	?	++		++		++	++		3	3	3	3	3	2	3
S7	0	0	0	0	?	?	-	-	++		?		-	0		?	3	3	3	3	3	3
S8	0	0	0	0	0	0	0	-	++	0	+	+	+	++		+	-	3	3	1	0	1
S9	++	++	++	+++	+++	++	++		+++		++	+++	+++	+++		++	-	++	3	3	1	3
S10	++	++	++	+	?		?		++	–	?		++		-	++	?	-		2	1	3
S11	++	++	++	++	0	0	++		++		+	++	++	+		++	0	0	+	-	2	3
S12	-	0	+	+	+		-	—	++	–	0		0			-	-	-	-	-	-	3

Direction and strength of action

+++	—	Strong	0	None	
++	–	Moderate	?	Unknown	
+	-	Weak		Uncertain	

Strength of interaction or driving force

0	None
1	Weak
2	Moderate
3	Strong

The column and row headings refer to the driving forces outlined in the text. The ranking and classification of the driving forces was determined from the scores given in the sector below the diagonal. A '+' indicates a driving force promoting invasions and a '–' a force retarding them. The sector above the diagonal indicates the strength of the interactions. The values on the diagonal indicate the relative strength of the driving force.

Ranking Driving Forces and Their Interactions

The analysis above identified a long list of secondary driving forces. We developed a matrix to help us rank the driving forces by summarising our understanding of:

1. whether there is a strong interaction between the driving forces *per se* (Table 1, above the diagonal),
2. the relative strength of the driving forces (the diagonal), and
3. whether these interactions between driving forces (below the diagonal) could be: (i) promoting invasion, (ii) retarding it, (iii) uncertain or (iv) unknown.

The strong secondary driving forces (i.e. those with a multitude of links in Fig 1) at the international scale generally strongly promote invasion. They influence activities which directly increase the number of propagules arriving in the country, mainly arising from the increased opportunities for importing alien organisms deliberately or inadvertently. All driving forces related to the movement of propagules such as the globalisation and expansion of trade links have a strong influence on intensifying invasion.

Listing the uncertainties

The summary matrix enabled us to identify the uncertainties (blacked out in Table 1), i.e. those factors which have a significant impact and whose impact can be either positive or negative depending on circumstances or unpredictable future events and developments:

1. The outcome of the development of invasion ecology into a robust and predictive science (I8).
2. The likelihood of the promulgation and implementation of international treaties aimed at limiting and preventing dispersal (I10).
3. The outcome of economic trends in South Africa and their impact on invasions (S2).
4. The possible changes in laws, policies and regulations governing alien species in South Africa (S5).
5. The effects of the changing perspectives and paradigms of conservation (S10).
6. The status of horticulture involving alien species in South Africa (S11).
7. Changing perspectives regarding alien species among the politicians and general populace (S12).

These uncertainties now provide the basis for developing an understanding of the underlying patterns and the identification of the key uncertainties.

Classification of uncertainties and developing the scenario axes

The next step is to rank the uncertainties and use this process to identify the underlying logics which provide the axes for the scenarios themselves (see Schwartz, 1992). The first two uncertainties identified earlier (I8 and I10) are international and therefore external to South Africa. Although internal uncertainties are, in some measure, dependent on international uncertainties, the internal ones are those South Africans can track and influence most easily. They are, therefore, our key uncertainties. This does not mean that we ignore external uncertainties, only that they are considered in relation to the internal ones. The remaining five uncertainties were assessed and numbers 3 and 4 (S2 and S5) were clearly more influential throughout the country than the remaining three (S10-S12), although it is clear that public and political support (S12) is essential for the development and effective implementation of policies, laws and regulations (S5). Economic trends (S2, uncertainty 3) have an overwhelming influence on what happens in the rest of the country, on most of the other driving forces, and thus on invasions. But the future state of the economy is quite unpredictable, so this key

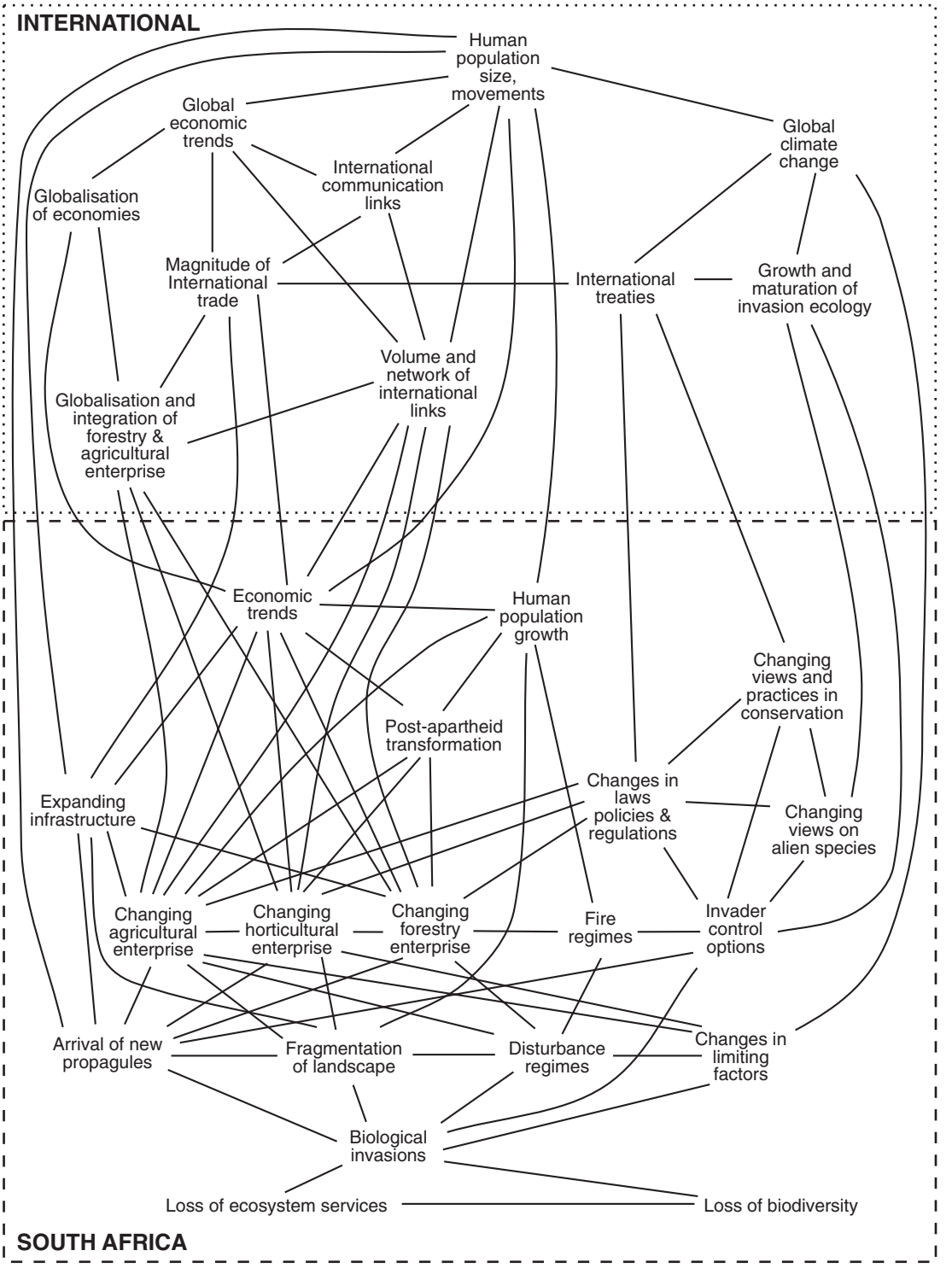

Fig. 1 A summary of the driving forces for biological invasions illustrating their multi-dimensional nature and complex interactions.

uncertainty provides the **"The Strength of the Economy"** logic (Fig 2). The other key uncertainty is the impact of possible changes in laws, policies and regulations which address biological invaders either directly and indirectly. Thus the second scenario logic is **"Laws, Policies and Regulations"**.

Fleshing out the scenarios

The scenario or story is developed in the following manner: using our matrix of interactions again, we developed for each quadrant of the scenario axes, or logics, the likely outcomes of the interactions in the form of description of the outcomes of the driving forces and their interactions (Fig. 3).

Naming the scenarios

An important part of scenario development is the naming of scenarios (Schwartz, 1992). These should conjure up an image of what occurs within that scenario. They convey immediately the essence of the scenario without having to spell out all the details. Based on the descriptions developed for each scenario (Fig. 3) we have named our scenarios as follows: New Mosaic, Garden of Eden, Green Desert and Another Farmyard (Fig 2).

Creating stories and assessing the implications of the scenarios

The implications of scenarios are one of the most important parts of scenario development. Unfortunately, this aspect is one that too often gets ignored and readers are left to interpret the scenarios themselves. The intention of developing the implications of scenarios is to create the context for the planning and actions that should follow in order to cope with each future should it happen.

GARDEN OF EDEN, with its strongly performing economy and coherent and vigorously implemented laws, policies and regulations, suggests a dichotomy of driving forces. Ongoing invader control programmes are well funded by the strong economy. However, stronger trade links and higher frequency of trade movement increases the likelihood of the arrival of new propagules either intentionally or inadvertently. The increased economic activity increases the rate of movement of propagules via more active seed companies, intensified agriculture and the transport of earth-moving equipment. Thus control efforts need to be focussed at potential points of entry like the various ports, and the importers of alien plants such as the agricultural and forestry industries. Screening of imported materials is comprehensive and effectively enforced. Further afforestation takes place among small growers who could be subsidised as part of government development plans. Land redistribution and reforms within the country are orderly. The conservation ethic is strong at all levels of society. In order to slow the current invasions, research and development of biological countermeasures is required. There is widespread education on the dangers of importing potentially invasive material.

The rigorously implemented regulatory environment has an appropriate measure of incentives and coercion. For example, an economic charge for water is introduced and land-owners pay for the excess that woody invaders are estimated to use. This provides incentives for land-owners to control alien invaders on their land. This scenario has the most favourable outcome, with the least impact by biological invaders.

ANOTHER FARMYARD represents a strong South African economy but a weak regulatory/policy environment scenario. This scenario implies a *laissez faire* or free-for-all attitude among people and results in a variety of land uses and in poor management of land resource issues. The landscape becomes highly fragmented with large numbers of small holdings. The general level of environmental ethics is poor, especially in agriculture. Timber

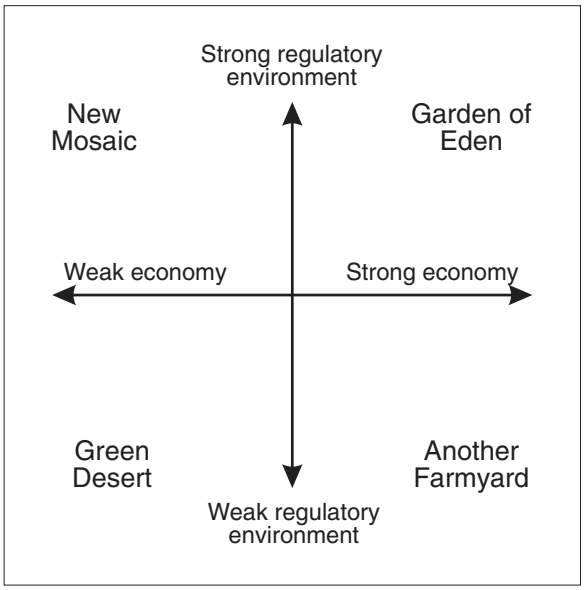

Fig. 2 Scenario logics and names.

High population growth rate. Urbanization rate increases. Growth of infrastructure, stagnates.

Land and wealth distribution is orderly, but land hunger slows growth in reserves, biosphere zones and conservancies.
Increased patch burning and overgrazing.
More small plantation growers/ mixed farming system in new areas.
Afforestation by commercial timber plantations slow. Alien vegetation heavily utilized by rural people.

National weed strategy is in place, implementation is weak.
No enforcement of the Forestry and Agricultural Acts Invaders. are declared as SFRAs, but regulations are not enforced.
Screening and quarantines is limited.
Tight regulations but limited control over use of GMOs.

Maximum yield farming with heavy use of fertilizers.
Catchment Management Authorities struggle to be effective.
Unregulated livestock movement.

Funding of bio-control research and implementation concerns mainly agricultural weeds.

Population growth stabilizes, Urbanization rate slows Infrastructure increases – electrification of rural areas.

land and wealth distribution is orderly.
More small plantation growers/ mixed fanning systems in new areas (subsidy schemes and financial assistance for growers) – growth of monolithic plantations slow.
Growth in reserves, biosphere zones and conservancies – tourism and hunting safaris increase.
Growth in horticulture and an increase in demand for alien species.

Weed strategy is in place – control is highly coordinated.
Screening and quarantines are in place.
General public are concerned with invader species.
Fertilization rates reduced.

Catchment Management Authorities are operating.
Unregulated livestock movement.
Tight regulations regarding testing and use of GMOs.

Significant funding for biocontrol agents for agricultural and general ecosystem weeds

Strong regulatory environment

Weak economy

Strong economy

Weak regulatory environment

High population growth rate. Disease rampant.
Urbanization rate increases. Growth of infrastructure stagnates.

Land and wealth distribution disorderly, extensive subsistence farming.
Conservation areas converted to farming.
Increased patch burning and overgrazing.
More small plantation growers/ mixed farming system in new areas.
Alien vegetation heavily utilized by rural people.

No national weed strategy.
No screening or quarantines of alien species.
No enforcement of die Forestry and Agricultural Acts .
Laissez faire attitude towards GMOs.

Limited growth of Horticulture.
Failure of Catchment Management Authorities .
Unregulated livestock movement.

Population growth stabilizes, Urbanization rate slows.
Infrastructure increases.

Land and wealth distribution haphazard.
More small plantation growers/ mixed farming system in new areas (subsidy schemes and financial assistance for growers) – growth of monolithic plantations slow.
Tourism and hunting safaris increase.
Growth in horticulture and an increase in demand for alien species.

No strategy exists for weeds – control is fragmented and uncoordinated.
Poor integration of weed control and land management.
Screening and quarantine is minimal.
Only conservation minded people are concerned with invader species.
Maximum yield tanning with heavy use of fertilisers.

Catchment Management Authorities are registered but are not effective.
Unregulated livestock movement. *Laissez faire* attitude towards GMOs.

Funding for biocontrol agents and implementation mainly for agricultural weeds

Fig. 3 Scenario logics and the key elements and implications of each scenario.

for the export market is grown in well managed plantations relatively free of invaders, but the plantations used for local wood supplies and the pulp and paper industry are less disciplined. Although the economy may be doing well, government is sidetracked by other issues.

Laws, policies and regulations are weak and implementation non-existent. The lack of policies and regulations implies less knowledge and awareness of the dangers of biological invaders. The rate of introductions of propagules increases. People bring in new species for possible economic advantage. The environment becomes "dirty" because of the presence of numerous different species. The variety of alien species is higher than in other scenarios. The strong economy shows little care for the environment. This is different from the *New Mosaic* scenario, which implies a land-care ethic that is hampered by a lack of funds. Biological counter-measures are more focussed on agricultural crops, where there is a direct economic impact. There is poor integration of weed control and land management. There is a continuous and expensive effort to contain the spread of invaders in some places, such as important catchments and conservation areas, but the problem is not addressed at a strategic and national scale.

GREEN DESERT represents a weak South African economy and a weak regulatory/policy environment. In this scenario, government-sponsored control programmes have collapsed for lack of funding as a result of the weak economy, but fuel requirements of the rural poor keep some woody invaders in check. The poor performance of the economy means that the frequency of international trade, and therefore frequency of arrival, is reduced. The threat of invaders in this scenario therefore originates from those plants already within the country. Low cost methods for invader control are especially required within this scenario, but lack of funding constrains research and development of bio-control agents. A specific danger within this scenario is also the possibility of international organisations using the weak laws, policies and regulations and the financial attractions of foreign organisations investing in the country to test GMOs in South Africa. Both driving forces combine, resulting in a double jeopardy.

Mountain catchments are especially vulnerable and convert to pines in the western and southern Cape mountain catchments. Fires become very intense, dangerous and costly to combat. Financial losses are significant. Soils are damaged after fires, erosion results and sedimentation of reservoirs is increased. Significant loss of biodiversity occurs in places. On the eastern escarpment frequent fires in the grasslands keep out the woody invaders. However, riparian zones are also increasingly invaded and significant losses of water take place. Erosion occurs here too, leading to increasing sedimentation in reservoirs. Loss of grazing occurs. Significant streamflow reduction by alien woody plants in places is concomitant with a loss of biodiversity, a loss of habitat, an increase in fire hazard and a substantial loss of productivity of the land.

NEW MOSAIC represents a weak South African economy but a strong regulatory/policy environment. In this scenario, the South African economy remains at the mercy of the international economic condition and local political and economic failings. But the internal development of policy relating to invaders is strong and coherent. The government knows what to do, but lacks the resources to do it. It concentrates on prioritizing the funding, and there are intense debates around how those priorities are determined. The landscape is an irregular patchwork of large wealthy farms and a sprawl of small holdings which are a result of land redistribution on the other hand. In this scenario, attention is given to prioritising areas for clearing and control efforts. The government cares about the problem of biological invasions but doesn't always have the financial resources to do the job as a result of the weak economy. Invasion therefore occurs to some degree over the whole landscape. At the same time, the rate of introduction of invaders slows because of reductions in trade, investment and the movement of propagules around the country.

Spread of biological invaders increases in general, but small amounts of money are available for controlling invaders in prioritized areas. The landscape takes on a patchwork nature with dense infestations of invaders in some places and none in others. The poor state of the economy also increases pressure for subsistence farming. Blocks of homogeneous land cover change into a patchwork of small and large land holdings.

Looking for the warning signals

An important aspect of scenarios is that they allow the participants to identify the warning signals that indicate that a particular scenario is coming true. They can, therefore, anticipate outcomes and take action before a particular scenario might play out. In this way the scenarios are also less open to interpretation later on when there may be more contention about the implications of the trends that are emerging.

In our scenarios, the most important warning signal is whether the government manages to develop and implement the appropriate policies, laws and regulations when it has the greatest opportunity for change, which the present. Failure to do this will activate the driving forces which will encourage a future in which a weak regulatory environment becomes a dominant force. Because of the nature of biological invasion, where the problem gets worse the longer nothing is done, the lack of sufficient laws, policies and regulations will be especially invidious. The current laws and regulations *vis à vis* biological invaders should be revisited in the context of all driving forces and not just the particular species.

Curve balls

There may be some driving forces that can not be identified at this stage and we also cannot be certain about whether they will become dominant or not. An example that is very recent on the scene is the carbon sequestration (or carbon banking) policy which allows some countries to maintain carbon outputs while funding other countries to afforest significant areas to create an equivalent carbon sink. Afforestation is a significant driving force of biological invasion in South Africa. This policy could become a threat in the *New Mosaic* or *Green Desert* scenarios where the financial attraction is great in a poorly performing economy.

Alternative scenario names

One of the characteristic scenarios is called the "*Official Future*"; this involves a set of implicit assumptions which underlies most institutional policies that say things will work out tomorrow – all that has to happen is that the right people put their policies into effect, or that current policies are acceptable and all that needs to be done is implement them (Schwartz, 1991). The *Official Future* is often the propaganda line of government and bureaucracies, but it represents a significant danger because it precludes actions that could have important impacts at the later crucial stages (Schwartz, 1991). In this case *Garden Of Eden* would be the *Official Future* scenario but it remains to be seen whether the government will put the necessary investments into managing biological invasions. Likewise there is also the scenario "*Worst Nightmare*". This would mostly be equivalent to *Green Desert*.

Conclusions and recommendations

In South Africa, policies, laws and regulations that are coherent and arise out of a single piece of law such as an act of parliament, will be one of the strongest contributors to having an impact on biological invaders. However, it is critical that politicians and society support the spirit and objectives of these laws. If they do not, it will be virtually impossible to implement those laws

and achieve the desired objectives. Despite significant efforts, the number of invasions is unlikely to decrease significantly in the medium term and the total number of invasive species in the country will increase. The critical factor is the achievement of economic growth rates that will enable the substantial investments in implementation and in control programmes and measures to be made. The economic performance of South Africa is heavily dependent on external influences, so we should put the same emphasis on this as we do on trying to influence our impacts on biological invasions.

We believe that this analysis shows clearly that to make a difference we must focus where the leverage is – on the human dimensions, and less on the ecological and biological aspects of invasive species. We need to start by making sure that policies, laws and regulations are effective and then implement and police these rigorously while making sure that we have the necessary support from society. Finally, we need to make plans to track the trajectories of the uncertainties, identify them and begin adapting to the implied futures now.

In closing, we echo and support Elton's (1958) concern about the possible consequences of biological invasions if people do not change their ways: "If we look far enough ahead, the eventual state of the biological world will become not more complex but simpler – and poorer" (Elton, 1958).

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Perception and "human nature" as factors in invasive alien species issues: a workshop wrap-up on problems and solutions

Maj de Poorter

Introduction

Based on previous papers in this book, I have tried to wrap up some thoughts on the role of "human nature" and perception in the invasive alien species issue. This includes an exploration on how such traits and perceptions can be part of the solution in the fight to prevent further loss of biodiversity due to alien invasion.

Workshop participants have for instance mentioned primal motivations like the need for food, the need for shelter and the need to ensure survival, the latter in modern times including the need to earn an income (Mack, this volume). They mentioned how these primal motivations have been a driving force for a large number of alien introductions in the past (e.g. crops and other agricultural species). Other human traits, for instance a wish to belong or a wish for power and/or freedom, have also contributed. Better understanding of these human factors can play a role in increasing understanding about invasive alien species, and about the need to prevent further invasions and mitigate existing ones. The depth of understanding is also influenced by the scale used when considering an issue, and by the degree of complexity present.

Furthermore, common traits like a wish for fairness and love of challenge can be extremely beneficial when applied to the invasive aliens issue in the right way.

The issue of scale

It was pointed out by one of the papers that matters of scale influence people's awareness: an individual can easily understand the consequences that his/her activities will have directly for him/herself, less easily the consequences for the local community, let alone the nation, continent or globe – not even to mention the universe! The issue of alien invasion is usually one where the effects of an individual's activity (e.g., the effect of bringing home a "nice plant" found while on holiday elsewhere) may show its insidiousness only after a considerable lapse of time, and possibly at quite a distance from the individual's immediate surroundings (e.g., twenty years later the plant has established, spread, and invaded an isolated national park). It would be unrealistic to expect normal standard household individuals to be able to routinely consider possible effects of their activities on a national scale. This is of course why legislative and institutional rules and procedures need to exist, for instance to prevent unauthorised or unintentional introductions and to regulate intentional ones. However, in order for such rules or procedures to be fully supported and implemented, citizens need to be able to understand the larger picture, much removed from their daily immediate surroundings. This is difficult – but not impossible. After all, there are areas, like sports, where most average citizens very easily

switch geographical scales: from supporting the local team to supporting the national team or even the only remaining "African" or "European" (or whatever) team in the competition.

Another issue of scale, but not in a geographical or a time sense, is the choice of overall context when looking at an invasive alien species issue. For instance, eradication by manual, physical means may be balked at in some instances, due to considerations of fiscal cost. In other instances, consideration may give more weight to environmental benefits as a balance to simple "dollar" considerations, while in yet other circumstances the employment that would be created may be thought to be such a social benefit that the financial implications become almost irrelevant (see Noemdoe, this volume). Therefore, if a proposed and necessary mitigation or other management scheme is met with "sorry, too expensive", the first question asked may usefully be: "are you truly looking at it in the full, fiscal, environmental and social context?"

The need for food, shelter and work

Food, shelter, and income are primal motivations that have to be met by humans to ensure survival. They have been the cause of a vast number of deliberate introductions of alien species, associated unintentional introductions, and many cases of aliens turned invasive. Yet they are also very powerful forces that can be harnessed for positive change. For instance, ecotourism provides livelihoods and at the same time provides an incentive for protecting endemic species against bio-invasions. The "Working for Water" Programme (Noemdoe, this volume), is a particularly poignant example of a fight against invasive aliens which is successful and well supported because it has been emphasised (and widely understood) that it actually protects livelihoods. This emphasis even finds expression in the name chosen for the programme; another title, for example "let's eradicate the alien trees" would have been unlikely to score the same amount of high level ministerial and public support, simply because of the choice of words.

The wish for freedom and/or power

Human desire for freedom and/or power nowadays extends to rather mundane matters which in turn encourage continued intentional introductions, e.g., the wish to grow whatever you like in your garden, have a variety of pets as an option, buy exotic foods (see Low, this volume, and Reaser, this volume). It can also be a source of resistance if rules or changes are imposed from above; it can create a distrust of authority, of "government" or of international bodies that are trying to regulate certain types of activities.

On the other hand, the individual's and community's high appreciation of decision making power means that "empowerment" is a potent potential force. Involving the local community can result in formal or informal adoption of certain biodiversity-rich local areas which then are patrolled and checked regularly, allowing for ongoing management of alien invasives; consulting with (and listening to!) communities may well complicate management because there will be the need to allow for diversification, but it will also result in increased chances of continuous support (see Warren, this volume). For instance, in New Zealand, possum eradication uses chemical methods in some areas, whereas mechanical removal (trapping, shooting) has been used in others when it became clear that the local community was strongly opposed to the use of chemical methods in an area of high unemployment.

The need to belong

In the past, immigrants have invariably brought animals and plants with them from their "home", not only for utilitarian purposes, but also to create a "new" home or "home away from

home". Hence the abundant "English" bird population of blackbirds, thrushes and sparrows that will greet visitors to New Zealand. It is an understandable part of human nature; after all, the familiar plants, animals and landscapes profoundly influence individuals and whole cultures alike.

How can that need to belong be harnessed in the prevention of further biodiversity loss through invasion? By encouraging pride in your local place on the planet. By explaining, for instance as part of the school curriculum, that every region has its biological distinctions, and that we have a choice of either keeping and protecting our endemics and other natives, or allowing global "blandification" to replace them. A "Support New Zealand-made products" campaign encourages us to support our own economy and "support our special and unique biodiversity" is a widely endorsed attitude in New Zealand. Many may not be able to tell you exactly which plants and birds are native and which ones are not, but almost every single New Zealander knows that there is such thing as a kiwi, and that kiwi are unique and irreplaceable and "ours" to protect … and hence they support eradication of introduced predators on the national bird. Taking pride in what makes one's own area different can provide a great sense of belonging. It is not a big step to get the message across that this uniqueness will not survive if alien invasions are left unchecked.

Fairness

Another fairly widely represented human trait seems to be the attempt to deal with issues of fairness. This is why in any David and Goliath situation we tend to be on David's side. If the picture perceived is one of big humans versus "poor little fluffy squirrels", sympathy will be with the squirrels (see Genovesi and Bertolino, this volume). In the portrayal of "the army" versus the "wild" Kaimanua horses in New Zealand (Veitch and Clout, this volume), a lot of people's sympathy was not with the army. In addition, wishing to remove an IAS may be portrayed as "xenophobic" or even provoke comparisons with Nazi attitudes.

However, the same desire for fairness is also what makes us dislike bullies and pushy people (or species). So, imagine the previous picture recast as the "big bully grey squirrel" invading red squirrel habitat in Italy. In addition, to those who like using second world war human analogues, it may be pointed out that leaving alien invasion unchecked will eventually result in almost complete global domination by the relative few, whereas preventing new invasions and mitigating existing ones will result in a continued co-existence (on a GLOBAL scale).

A cautionary note needs to be added here: in the context of "fairness" (as well as ecological accuracy) it needs to be pointed out that it is counterproductive to vilify or "demonise" invading species. An invasive alien species is not a bad species, only a species behaving badly in a place where it does not belong. In its home country, the same species may well be duly and strictly protected.

Change of perception over time

In the previous paragraphs, I gave some examples of how people's perception (and values) can exert a major influence over the outcome in invasive alien species issues.

I am a firm believer that perceptions and hence attitudes can change in time, and that increased education and awareness-raising on invasive alien issues are not only very urgently needed but also a very worthwhile investment of resources.

It is sometimes said that the concept of a species being "fine" in its native range, but doing ecological damage when it is "out of its place" is a difficult one to understand for the public, especially if the species in question is a pretty plant or cuddly furry animal. My view on this is much more optimistic: most people are perfectly able to understand this and act on it, provided

someone has taken the trouble of explaining it to them. It was understood perfectly by a nine-year-old lately who succinctly put it as "of course. Just like my younger brother. I love him dearly, but when he comes into MY room and messes it up, he's a little pest".

Conclusion

Human nature and perceptions play a very big role in the invasive alien species issue. I have tried to provide some examples in order to show that these human attributes, while contributing to the creation of IAS, can also contribute to the solutions. The challenge will be to present IAS issues in the appropriate context so that maximum awareness, understanding and support for necessary management action can be generated.

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