INVASIVE ALIEN SPECIES AND PROTECTED AREAS: SOME OF THE KEY ISSUES

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Jim Mitchell, research zoologist of the Department of Natural Resources Queensland, Australia, reports that in some parts of the World Heritage listed rainforests in Queensland, 98% of sampled earthworms are aliens. The feral pig is suggested as the principal distributing agency, one alien helping to transmit another. He has no idea of the ecological impacts of this and no funding is available to study this problem. He concludes, "As with most alien species problems, we will have to find out in the future when the problem becomes obvious and by then too late to stop".

INTRODUCTION

For millennia, the natural barriers of oceans, mountains, rivers and deserts provided the isolation essential for unique species and ecosystems to evolve. In just a few hundred years these barriers have been rendered ineffective by major global forces that have combined to help some species travel vast distances to new habitats and become invasive alien species that have negative impacts on native biodiversity. The globalisation and growth in the volume of trade and tourism, coupled with the emphasis on free trade, provide more opportunities than ever before for species to be spread accidentally or deliberately. Customs and quarantine practices, developed in an earlier time to guard against human and economic diseases and pests, are often inadequate safeguards against species that threaten native biodiversity. Thus the inadvertent ending of millions of years of biological isolation has created major ongoing problems that affect all countries.

Ecosystems that are geographically or evolutionarily isolated -- notably oceanic islands, certain mountains and lakes -- are known to be particularly vulnerable to invasion. Such systems have been isolated over millions of years, thus favouring the evolution of endemic species (those found nowhere else). However, the evolutionary processes associated with isolation make such species especially vulnerable to competitors, predators, pathogens and parasites from other areas. Multi-island states like Indonesia and groups of islands like the Galapagos can be extremely vulnerable to transfers from one island to another because the islands, even relatively close to each other, may each have different endemics.

It is sometimes suggested that biodiversity helps to protect against invasions, with the argument being that systems with great species diversity are more resistant to new species coming in. However, Levine (2000) found that in a California riparian system the most diverse natural assemblages are the most invaded by exotic plants. Theory suggests that alien species should have a more difficult time invading a diverse ecosystem because the web of species interactions should be more efficient in using resources such as nutrients, light, and water than would fewer species, leaving fewer resources available for the alien species. But in even well-protected landscapes such as national parks, invaders often seem to be more successful in diverse ecosystems.

In a study of alien plant invasion in mixed-grass prairie at Theodore Roosevelt National Park, in western North Dakota, USA, Larson *et al.* (2001) found that while all vegetation types were invaded by alien plants, wetter communities had both greater numbers and higher frequencies of alien plants than did dryer communities. However, they also found a strong element of randomness, suggesting that prediction of risk of invasion will always involve uncertainty. Finally, despite well-documented associations between anthropogenic disturbance and alien plant invasion, they found that five of the six most abundant alien species had distributions unrelated to disturbance. They found riparian areas to be especially at risk of invasion.

Thus diversity may well matter at the level of the small experimental plot but in larger communities the size of a protected area, other factors that operate across a broad scale are able to swamp the effects of biodiversity and enable both native and non-native plants and animals to flourish. So diversity helps fend off invasives but its effects are wiped out by other factors at larger scales. Levine concludes that the most diverse ecosystems might be at the greatest risk of invasion, while losses of species, if they affect neighbourhood-scale diversity, may erode invasion resistance.

THE IMPORTANCE OF INVASIVE SPECIES AS A PROTECTED AREA MANAGEMENT ISSUE

Protected areas are established at least partly to conserve native biodiversity, and many have biodiversity conservation as their main objective. But virtually all protected areas in the world are significantly affected by invasive alien species, and those species present a profound threat to native biodiversity (see box). In the US, feral populations of horses and donkeys have reached some 50,000 animals since they were introduced sometime before 1750. By grazing heavily on the native vegetation, they allow non-native annuals to displace native perennials, and cost the nation an estimated $5 million per year in forage losses, implying that they eat forage worth US$100 per animal per year. They also diminish the primary food sources of native bighorn sheep and seed-eating birds, reducing the abundance of these natives (Pimentel *et al*., 2000). And goats introduced on St. Clemente Island, California, have caused the extinction of 8 endemic species of plants and the endangerment of 8 others (Pimentel *et al*., 2000).

BOX 1: Main Threats to Threatened Species in the US (categories are non-exclusive and therefore do not sum to 100 percent). Source: Wilcove, *et al*. (1998).

Cause	**All species (N=1880)**	**Vertebrates (N=494)**	**Invertebrates (N=331)**	**Plants (N=1055)**
Habitat degradation/loss	85	92	87	81
Alien species	49	47	27	57
Pollution	24	46	45	7
Over-exploitation	17	27	23	10
Disease	3	11	0	1

The earthworms invading the World Heritage rainforests of Queensland are just one example among many. The Galapagos Islands, another World Heritage site that is justly celebrated as the stimulus for Charles Darwin's theory of evolution, is so heavily threatened by invasive species that a major GEF project has recently begun to deal with the multiple threats posed by invasives. For example, the endemic birds of the Galapagos are confronting serious problems posed by invasive species, especially of diseases. Newcastle disease, Marek disease, avian pox, and perhaps avian malaria are now posing a threat to the birds, having arrived in the Galapagos with the introduction of chickens, pigeons, ducks, and turkeys (www.darwinfoundation.org).

Another invasive alien species, white pine blister rust (a fungus from northern Europe) now infects almost every white bark pine tree in Glacier National Park (another World Heritage site). Indeed, the white pine blister rust is killing off the white bark pine trees in almost every high-elevation national park in the American West. This is not simply an aesthetic matter, as the white pines grow where other conifers do not, holding the soil, regulating snow melt, and producing nuts that feed numerous birds and mammals. They appear to be essential to the survival of grizzly bears in such areas.

This sad story can be repeated throughout the world, with only the species names changing. No protected area in Australia or New Zealand is free of invasive alien species. Wetland protected areas throughout the world are affected by invasive species of water plants (such as water hyacinth) or invasive species of fish. The Crater of Ngorongoro in Tanzania, another World Heritage site, is infested by Mexican poppy, occupying significant areas of the Crater floor; these areas are easy to identify because they are essentially void of grazing mammals and their predators.

In Mahali Mountains National Park, Tanzania, *Senna spectabilis* from tropical America is considered a problem. *Chromolaena odorata* from South America is currently invading most of the forests of West and West-Central Africa and represents a very serious threat to forest regeneration because it excludes all other plant life,

including tree seedlings and saplings. While this species has apparently not yet reached east Africa, it seems to be spreading eastward and is now widespread in Gabon (Struhsaker, 2002).

While protected areas may be considered by some to represent "nature", the reality is that we are dealing with ecosystems that have been significantly influenced by people; some have even called these "engineered ecologies". This calls for a much more conscious and better-informed management of ecosystems, including dealing with alien species. The introduction of IAS can bring about very rapid biological change, which can overwhelm adaptive mechanisms of modern societies.

Many invasive species have impacts on ecosystems such as changes in community composition and trophic dynamics. Some plants that alter nutrient cycling or hydrological systems are likely to have long-lasting effects on the ecosystem even after a successful control programme, and such effects may result in unpredictable outcomes such as new invasions. Introduced predators like feral pigs (an actual problem) and brown tree snakes (a potential problem) in Hawaii may also produce long-term effects on trophic interactions, resulting in unpredictable population explosions after their removal or control. Programmes aimed at restoring the original dynamics, in conjunction with control programmes, are most likely to succeed in restoring native communities. Invasion by other aliens may result from removal of competition, as demonstrated by the many examples in agricultural systems where successful biocontrol of one pest species results in the increase of an even worse pest. Such programmes increasingly are addressing the need to control an entire suite of current and potential pests. Identifying which aliens are strongly restricted by competition from the alien planned as a target of control may help in predicting the outcome of removal. In many cases, the underlying impacts of human landuse may overshadow any benefit of removing an alien. If human disturbance damaged the native community, and allowed an alien to become dominant, removal of that alien is unlikely to solve the problem. A change in human land use resulting in a return towards the original dynamics is necessary if we want to restore the native community.

Invasive species can have indirect impacts on species through affecting the way ecosystems function. For example, an endemic species of fox (*Urocyon littoralis)* found on just six of the Channel Islands off the coast of southern California is being affected indirectly by an invasive species of pig. Romer *et al.* (2001) suggested that the pigs that have been introduced by humans on to the Channel Islands acted as an abundant food source that enabled golden eagles to colonize the Channel Islands from the adjacent mainland, and subsequently prey on the island fox, a species that was unaccustomed to a threat from a major avian predator. The island spotted skunk (*Spilogala grachilis amphiala)* greatly increased as the populations of foxes declined, because the spotted skunks were nocturnal and able to avoid predation from the golden eagles. Another factor in this equation is that humans also led to the eradication of bald eagles from the Channel Islands, thus opening up a possible niche for golden eagles. Bald eagles tend to prey on fish, but were able to keep the golden eagles away from the islands.

Dangers from Invasive Species: the Case of West Nile Virus

In 2002, more than 3200 people contracted West Nile virus in the USA, with 177 deaths. The virus arrived in New York in 1999 from Israel and is carried by mosquitoes, but lives mostly in birds. It appears that only 1 out of 150 people infected actually becomes ill. But the bird populations of North America have been devastated, with fatality rates as high as 90% for crows, the species most sensitive to the West Nile virus. Birds of prey appear to be dying at 10 times their usual number in several states in the USA. More than 100 species of North American birds are known to be infected by the West Nile virus, but the ubiquitous house sparrow (itself an invasive species) carries the virus without showing symptoms. Endangered species of birds, such as the Florida scrub jay, could become extinct as a result of this invasive species. Europe, too, is affected by a closely-related virus, known as Usutu, which has killed thousands of blackbirds in Vienna (McKenzie, 2002).

Many of the species of birds infected by the West Nile virus in North America are migratory, posing the possibility that the West Nile virus could be spread throughout the Neotropics in the northern winter. Field biologists working in the Guanacaste Conservation Area in north-western Costa Rica have already observed a precipitous decline in the abundance of scores of species of small northern migrants, such as warblers and thrushes. While the virus has not yet been recorded, and the decline may be only temporary, the impact of a multi-species epidemic such as West Nile virus on the biologically diverse tropical forests is a matter of considerable concern. Protected area status will offer scant protection against this very real threat to the biological integrity of the Western Hemisphere.

Several invasive alien species of mosquitoes are capable of carrying the West Nile virus. These include *Aededes japonicus*, which arrived in the late 1990s and is found in Connecticut; and *Aededes albopictus*, which arrived in the early 1980s is found in northern New Jersey (at least). Both are said to be very efficient vectors of the West Nile virus, and vicious biters who bite during the day (Boyle, 2000). Many other mosquito vectors are found in the Neotropics, some native and some invasive.

It is clear that ecosystem management is an essential element in many approaches to dealing with alien invasive species. For example, European cheat grass (*Bromus tectorum*) is dramatically changing the vegetation and fauna of many natural ecosystems in North America, invading and spreading throughout the shrub-steppe habitat of the Great Basin in Idaho and Utah and predisposing the invaded habitat to fires. Before the cheat grass invaded, fires burned only once every 60-110 years, enabling shrubs to become well established. With the occurrence of fires every three to five years has come a significant decline in shrubs and other vegetation, leading to more effective establishment of cheat grass monocultures on five million hectares in this region. Animals dependent on shrubs and other original vegetation have been reduced or eliminated, demonstrating the cascading effects of AIS (Pimentel, *et al.*, 2000).

MANAGEMENT ISSUES FOR PROTECTED AREAS

The previous section has indicated how harmful invasive species are to protected areas. Dealing with this threat is a major management issue, including visitor relations, habitat management and external affairs.

Dealing with Visitors

Tourism is considered an efficient pathway for invasive alien species on sub-Antarctic islands such as south Georgia. Tourism to the island has tripled over the past three years to reach 15,000 in 1999. Part of the problem is that many tourists are visiting similar islands on the same trip, increasing propagule pressure more than would be expected from a single landing of a few people who spend an extended time on one island. Expert opinion considers that tourism poses considerable threats to the endemic biota of these islands because it increases the likelihood of invasive species arriving and becoming established (Chown and Gaston, 2000).

Backpackers may spread certain IAS, such as *Chromolaena odorata*, into remote parts of protected areas, because its seeds readily attach to clothing, boots, and backpacks. A possible management response is visitor education.

Species and Habitat Management

The Asian eel *Monopterus albus* has invaded the southeast USA. It is a prototypical invasive species, with an eclectic diet, high environmental tolerance, few natural enemies, and a high rate of reproduction and year-round breeding. Spreading apparently from Georgia and the Carolinas, the Asian swamp eels have almost reached the Everglades National Park, where they are likely to have a devastating impact on the native species (Robichaux, 2000). Methods for controlling the eel that are under discussion include a network of underwater electronic fences in strategic locations, dynamite (which doesn't work well on eels because they lack the large airbladder that makes fish susceptible to concussion blasts), and poisoning the entire length of infested canals in Florida (which might not be effective because the eels can simply raise their snouts above water and breathe air). Such extreme measures would certainly have very strong negative effects on all other aquatic life as well, so would likely meet with very strong protests by local residents and fishermen. This is very much a question of which is worse, the spread of the invader or the risk associated with containing it.

Knapp and Matthews (2000) found that the puzzling decline of the mountain yellow-legged frog in California's Sierra Nevada in protected areas that are relatively undisturbed and not affected by habitat alteration is due to the impact of introduced species of trout that feed on both tadpoles and adults. Enabling the frog to recover to a healthy population level will require eliminating all trout from many of the Sierra lakes. It is expected that the removal of trout from these lakes will cause virulent protest from some fishermen and local communities.

Because of the unpredictability of invasions, a monitoring plan needs to be implemented that emphasizes the most vulnerable vegetation types and includes searches for all known potential invaders; this step is essential for early detection as well as to determine which species are increasing in number and range. These monitoring results will allow the assigning of priorities for use of limited resources for alien plant control (Larson *et al*., 2001).

The isolation of island protected areas can be turned into an advantage by improving the capacity of governments to prevent the arrival of alien invasive species with better knowledge, improved laws and greater management capacity, backed by quarantine and customs systems that are capable of identifying and intercepting alien invasive species (IUCN, 2000).

Environmentally sensitive eradication also requires the restoration of the community or ecosystem following the removal of the invasive. For example, the eradication of Norway rats from Mokoia Island in New Zealand was followed by greatly increased densities of mice, also alien species. Similarly, the removal of Pacific rats (*Rattus exulans*) from Motupao Island, New Zealand, to protect a native snail led to increases of an exotic snail to the detriment of the natives. And on Motunau Island, New Zealand, the exotic box-thorn (*Lycium ferocissimum*) increased after the control of rabbits. On Santa Cruz Island, off the west coast of California, removing vertebrate grazers led to dramatic increases in the abundance of fennel (*Foeniculum vulgare*) and other alien species of weeds. Thus reversing the changes to native communities caused by aliens will often require a sophisticated understanding of ecological relationships.

Some species that are invasive in one country may be threatened at home. For example, the Bermuda cedar (*Juniperus bermudiana*) is threatened in Bermuda but is a self-regenerating timber tree in St. Helena (Spooner *et al*., 1993); *Melaleuca* is a rare species of plant in its native Australia, but is invasive in Florida, where it is a serious problem in Everglades National Park; the tree *Delonix regia* is in danger of extinction in Madagascar where it is native, but is naturalized and common in Puerto Rico (Lugo, 1997); and the African violet is common in much of the developed world but seriously threatened in its native Tanzania. Thus conservationists frequently are faced with situations where the only way of conserving a native species whose natural habitat has changed is to translocate the species to a more amiable habitat; another option is to take it into an *ex situ* facility for subsequent reintroduction (as with the blackfooted ferret, the whooping crane, and the Arabian oryx). Even where a population still survives, but only tenuously, a conservation measure might well be to extend it outside of the native range in hopes that it will become established. Indeed, the fundamental premise behind attempts to identify minimum viable populations is to take whatever management measures are required to prevent such populations from further decline, and indeed to enable them to expand. Such isolated small populations may quickly become genetically impoverished and inbred, requiring new genes to enable them to become more viable. This complicates the challenges faced by protected area managers seeking to include IAS issues in their species management programmes.

Dealing with the External Public

Philosophical issues cannot be separated from technical ones in the field of invasive alien species, requiring that the human dimensions be considered at the very earliest stages (McNeely, 2001). One critical issue is the definition of "native", involving at least three perspectives: time scales; boundaries; and the role of human agency. Regarding time scales, species are constantly expanding and contracting, sometimes with human help. Species recovery programmes often seek to reintroduce native species that subsequently were lost (for example, the Arabian oryx in Oman and Saudi Arabia, the wolf in certain parts of the USA, they lynx in the Swiss Alps, and beaver in Scotland). Boundaries are an issue where countries are contiguous with others, enabling species to move back and forth with or without human agency; and because our scientific understanding of species distributions is still very spotty, new discoveries may simply reflect insufficient knowledge. Kendall and Rose (2000) suggest that one of the greatest problems with the concept of "native" is that it commits us to supporting a flora that reflects a particular environmental and climatic state that in fact is dynamic, highlighting the irony that the increasingly strong attacks on non-native species come at the time when climates are changing rapidly.

Further speciation and development of biotic communities depend on organisms invading into novel habitats, sometimes hybridizing (Orr and Smith, 1998). Another point to be considered is that native status is determined by the technological level of the people who influence plant distribution, with hunters and gatherers often considered to be "natural" while industrial civilization is considered "unnatural". Many would suggest the transition began with the domestication of plants and animals, so that agricultural populations of humans are no longer part of nature (Webb, 1985). Kendall and Rose (2000) argue that the concepts of "native" and "alien" are based on value judgements associated with a selective timeframe, and a selective categorization of which types of humans can legitimately act as modes of dispersal. It appears that the rejection of human influence on nature reflects modern values rather than any objective reality.

One critical issue that can build on biogeographical principles is the definition of "native", a concept with challenging spatial and temporal scales. While every species is native to a particular geographic area, this is in fact a snapshot in time, because species are constantly expanding and contracting their ranges, sometimes with human help. For example, Britain has nearly 40 more species of birds today than were recorded 200 years ago. About a third of these are deliberate introductions, such as the Little Owl (*Athene noctua*), while the others are natural colonizations (May, 2000).

Thus conservation and preservation clearly are value-driven activities, leading to paradoxical situations where considerable "artificial" inputs of management effort are devoted to maintaining "natural" habitats. Human influences increasingly lead to fragmented habitats, and this will inevitably change the components and organization of ecological communities; thus the issue of the specialized roles of individual species may have diverted attention from the more interesting study of ecological flexibility and adaptation to changing conditions. One implication of this is that humans often act as forces of degradation but are not allowed to make a positive influence in essential harmony with nature. Restoration ecology therefore must become an active

partner in modern conservation, enabling humans to play a role in species recovery and explicitly recognizing that value judgements are involved in doing so.

Addressing the problems of IAS often is as much about politics as science. This requires bringing the public along with us as we decide how to address the problem. A major conflict in managing invasive alien species in protected areas is with the animal rights groups who care about the fate of single animals and therefore strongly resist any measures to eradicate them. The problem is exacerbated if the species are large and attractive to significant numbers of people, such as wild horses in the American West and in New Zealand. The invasive grey squirrel in Italy and England is a small-mammal example of this problem; eradication or control of such furry invasives is particularly difficult from a public relations standpoint. One answer to the animal rights perspective is that the CBD accepts that humans can harvest other species, and kill animals that threaten ecosystems.

Those who are responsible for marketing have much to teach protected area managers, who need to convince the general public that controlling an invasive species is in fact a noble undertaking. For example, the programme in New Zealand to control the invasive brush-tailed possum was called "Operation ForestSave" and all the promotional information showed lovely flowering native trees, without a cute furry possum in sight. In Europe, the issue might be presented as "Save the Red Squirrels", not "Kill the Grey Squirrels". And in Queensland, Australia, the endangered cassowary is used as the "front" for controlling feral pigs, fully involving community groups in the programme.

A GLOBAL STRATEGY ON INVASIVE ALIEN SPECIES

In order to draw more attention to the problem of invasive alien species, several organizations joined together under the banner of the Global Invasive Species Programme (GISP). They prepared a very useful toolkit of best prevention and management practices (Wittenberg and Cock, 2001), and this can be commended to protected area managers.

They also recommended 10 strategic responses to address the problem of invasive alien species:

1. Build management capacity.
2. Build research capacity.
3. Promote sharing of information.
4. Develop economic policies and tools.
5. Strengthen national, regional, and international legal and institutional frameworks.
6. Institute a system of environmental risk analysis.
7. Build public awareness and engagement.
8. Prepare national strategies and plans.
9. Build IAS issues into global change initiatives.
10. Promote international cooperation to deal with the problem (McNeely, *et al.*, 2001).

While successfully dealing with the problem of invasive alien species will require cooperation from many institutions, protected area mangers have a particular responsibility in view of their mandate for conserving native biodiversity.

CONCLUSIONS

Humans have the power to both dominate nature and exercise good stewardship, but our species seems to have a particular proclivity for shirking responsibility, or passing it on to others. We seem to be well able to live with contradictions and inconsistencies, manipulating information to suit our own ends.

We need to face some important questions. For example, could our attempts to maintain ecosystems in face of global change cause them sufficient stress that they change with or without invasive alien species? The answer is probably yes. But could we be hastening the success of an invader by not allowing the ecosystem to change and adapt to change as it occurs? By resisting change, may we be exacerbating the impact of aliens?

More fundamental, can the global reach of modern human society be matched by an appropriate sense of responsibility? Philosophical and ethical issues are central to considerations of IAS, as indeed they are to all of conservation. Despite the philosophical challenges posed by IAS, the threat to the integrity of protected areas is real. Dealing with this threat should be given much higher priority, in budgets, education activities, and management practices.

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