



Biological Invasion as a Global Change

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Editors

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Biological Invasion as a Global Change

Peter Vitousek
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Humans move many species from their native ranges to places all over Earth, both deliberately and inadvertently. Where those species establish new, self-maintaining populations, this movement leads to human-caused biological invasion. The thesis of this report is that human-caused biological invasions have become so widespread as to blur the regional distinctiveness of Earth's biota. That distinctiveness is itself an important component of Earth's biological diversity, and it contributes substantially to the maintenance of species-level and even human cultural diversity. Biological invasions thus represent an important component of anthropogenic global change.

Human-caused biological invasions have become so widespread as to blur the regional distinctiveness of Earth's biota.

Our view of the components and causes of global environmental change is summarized in Figure ii-1. Growth in population and resource use by the human population has entrained vast industrial and agricultural enterprises (top), involving extraordinary rates of energy use and an unprecedented mobility of people and goods. These in turn have caused a set of global changes in the Earth system that are relatively well documented and known to be human-caused (middle). Some of these changes result directly from human resource use, while others are caused by the accumulation of waste products; some are inherent to the scale of human activity, while others are avoidable. Global changes in this set interact with each other; they also cause changes in regional and global climate, and drive ongoing losses of biological diversity (bottom).

How important are invasions in comparison to other components of global change? That question is not easily answered, because the timing, scale, and consequences of each component of change are so different, and because these changes interact so strongly with each other. We believe that it is reasonable to suggest that other than the ongoing epidemic of extinction, biological invasions are the least reversible of the major anthropogenic global changes. We also believe that biological invasions are second only to land use/land cover change in driving global losses of biological diversity.

An estimate of the potential impact of biological invasion on biological diversity can be calculated using species-area curves. Preston (1960) used this approach in an analysis of the spatial distribution of breeding bird populations; he demonstrated that the slope of a regression of species number against the log of area would underestimate the total number of bird species on Earth substantially. Using an approach suggested at the meeting by Randy Westbrooks, we carried out a similar analysis of mammals, regressing the number of species on the log area of continents (using a database at the Center for Conservation Biology, Stanford University). The resultant plot (Figure ii-2) is strongly log-linear, with an *r-squared* of .94. Extrapolating this

relationship to the land area of Earth, if all the continents were combined into one land mass, that continent should support ~2000 species of mammals. In fact, the separated continents support 4200 species. This result suggests that if biological invasions were so widespread as to cause a complete breakdown of biogeographic barriers, the extinction of more than half the continental mammals (and most likely a larger fraction of those on islands) would be entrained. We believe that this analysis is at least as soundly based as calculations of entrained species loss due to land use change.

An appreciation of the global significance of biological invasions is not a new development. In his fundamental work "The Ecology of Invasions by Animals and Plants," Elton (1958) concluded:

Other than the ongoing epidemic of extinction, biological invasions are the least reversible of the major anthropogenic global changes.

"We must make no mistake -- we are seeing one of the great historical convulsions in Earth's flora and fauna. We might say, with Professor Challenger, standing on Conan Doyle's "Lost World" ... "We have been privileged to be present at one of the typical decisive battles of history -- the battles which have determined the fate of the world." But how will it be decisive? Will it be a lost world? These are questions that ecologists ought to try to answer."

Aside perhaps from the allusion, Elton's conclusion could hardly be improved upon today.

Biological invasions often are considered to be primarily a phenomenon of island ecosystems, whether of terrestrial islands in the ocean or the island-like aquatic and coastal marine ecosystems of continents. Indeed, there is no doubt that the consequences of invasions are particularly severe on islands (Loope and Mueller- Dombois 1989, Simberloff 1995, D'Antonio and Dudley in press). However, invasions of continental systems also are widespread -- and damaging in many cases. For example, the eastern deciduous forests of North America were cleared extensively in the last century, but they have rebounded substantially in this century; they are discussed widely as an example of the resilience of many natural ecosystems. A great deal of effort has gone into determining current and probable future effects of climate change, increased carbon dioxide concentrations, acid rain, and oxidant air pollution on these forests. However, the big change in this century has been the invasion of wave after wave of introduced pests and diseases (Castello et al. 1995). Some of these pests, such as the gypsy moth, consume a variety of species. Other, more specialized pathogens have eliminated the American chestnut (once the most abundant tree in the eastern United States) (McCormick and Platt 1980) and American elm (Huenneke 1983), and have greatly altered the dynamics of American beech, flowering dogwood, and other species. Several other widespread species are threatened. We suspect that invasions will continue to represent the most important environmental and economic threat to eastern deciduous forests for the foreseeable future.

We acknowledge that while all biological invasions represent an alteration of natural processes, we are not equally concerned with all of them. Many invasions reflect other components of environmental change, rather than being themselves drivers of change. For example, invading plants that stably occupy roadside areas cannot be regarded as serious threats to native biological diversity; they are mainly a consequence of land use change (which may itself threaten diversity). Moreover, some introduced species clearly are beneficial to humanity; for example, it would be quite a trick to support the population of the United States entirely on native foods. However, some invading species are damaging, either by degrading human health and/or wealth directly, or by affecting the structure and functioning of ecosystems, and/or the maintenance of native biological diversity. Harmful invasions might best be prevented by excluding all non-indigenous species, except for some that are specifically designated as "safe"

-- but once invasions occur, control and management will have to be focused on those species with the capability to act as agents of change.

In discussing invasions, it is hard to resist presenting case studies -- and we won't resist, not entirely.

Health

There are numerous examples of invading organisms that threaten human health; most infectious diseases fit in this category, over most of their range. Several centuries ago, the indigenous people of North America could cite smallpox as a devastating Old World invader (Crosby 1986) -- just as modern Americans can point to HIV. Another recent invader is the Asian tiger mosquito *Aedes albopictus*, which entered the United States in imported used automobile and truck tires, and which is an aggressive and effective vector for dengue fever and eastern equine encephalitis (Craven *et al*. 1988, Mitchell *et al*. 1992, OTA 1993).

We suspect that invasions will continue to represent the most important environmental and economic threat to eastern deciduous forests for the forseeable future.

Wealth

These are numerous examples of invading species that impose substantial costs on society in the invaded areas. Fouling of water intakes in North America by zebra mussels (*Dreissena polymorpha*) is a recent example, one that could cost water- using utilities $3 billion over a 10 year period (OTA 1993). Another example is the golden snail in Asian rice ecosystems. The golden snail was introduced deliberately to provide a source of export income for small farmers; it has been spread throughout Asian irrigated rice systems. However, the snail cannot be exported to Europe due to health regulations, it is not considered palatable locally, it spreads rapidly through irrigation systems, and it voraciously consumes young rice plants. Naylor (submitted) calculates that in the Philippines alone, the golden snail costs farmers around $55 million per year -- one third of that for molluscicides, one third for labor replanting damaged areas, and one third in lost yields. That represents 14% of the gross income from Philippine rice -- and this in a developing agricultural system that is neither plagued by overproduction nor dominated by a few wealthy producers.

Effects on ecosystems

Invasions that alter the structure and/or function of invaded ecosystems are particularly threatening; they do not merely compete with or consume particular native species, they change the nature of the ecosystem in which all natives survive. In other words, they do not just add players to the game, they change its rules -- often to the benefit of that and other invaders. Many species of grasses provide clear examples of invaders that alter ecosystems, in many regions of Earth. Pasture grasses have been introduced deliberately, particularly from the old world into the new; other grass invasions have occurred through contaminated seed lots (Mack 1991), while still others have been transported as ornamentals. In the Intermountain West of the United States, cheatgrass (*Bromus tectorum*) apparently entered in contaminated seed. Once established, it spread in the interstices of sagebrush shrublands -- making a continuous layer of fine fuel that can carry fire effectively. After fire, cheatgrass (an annual) regrows more rapidly than woody plants; after several fires in succession, cheatgrass is the dominant plant, and the probability and extent of fires increases enormously (Whisenant 1990, Billings 1990). Cheatgrass now dominates more than 40 million hectares in Western North America

(Stewart and Hull 1949, Whisenant 1990); in pastures of its range, the fire return interval has decreased from 60-110 years to 3-5 years, and the average size of fires has increased by orders of magnitude (Whisenant 1990).

Similar dynamics are set in motion by grass invasions elsewhere, including African C4 grasses in humid regions of Australia, tropical America, and Oceania, and other African and Mediterranean grasses in semiarid areas of Australia and the Southwestern U.S. (American woody plants -- but rarely grasses -- return the favor to the Old World.) These grass invasions interact with land use change in a positive feedback cycle (Figure ii-3) that reinforces forest clearing, and prevents the re-establishment of forests following abandonment of agricultural and pastoral land (D'Antonio and Vitousek 1992).

Loss of biological diversity

Several centuries ago, the indigenous people of North America could cite smallpox as a devastating Old World invader, just as modern Americans can point to HIV.

In North America, the most immediate threats to biological diversity caused by biological invasions occur in aquatic ecosystems. Individual drainage systems and lakes may function as islands, and be more susceptible to alteration by invasions than are surrounding terrestrial areas. At the same time, invasion pressure on aquatic systems is substantial -- from aquarium fish dumped into culverts to multimillion dollar efforts to establish sportsfisheries using introduced species, some from other continents (especially the German brown trout), and others transported well beyond their native ranges within North America. Moreover, the most popular introduced sports fish are top carnivores -- precisely the group likely to have the greatest effect on food webs in recipient lakes and streams, and to exert top-down pressure on all other organisms in the system.

The consequences of this conjunction of factors are predictable, and depressing. From one-third to two-thirds of all amphibian, fish, crayfish, and mussel species in North America are rare, declining, or endangered, or already extinct. Of the 86 native fish officially listed as threatened or endangered in 1991, 44 were affected by introduced fish -- 29 of those by introductions for sportsfishing, 11 by trout alone (Wilcove and Bean 1994).

Even invasions that do not change ecosystem structure and function appreciably can nevertheless alter biological diversity; for example, Medeiros et al. (1992, 1993) report that an Australian tree fern which invades Hawaiian forests appears very similar to native tree ferns -- except that the natives serve as important substrates for epiphytic plants, and the invader does not.

Discussion

These particular cases are not atypical examples of biological invasion and its consequences -- except in that they have been documented far better than have most invasions. Similar examples can be found almost anywhere. What isn't always clear, even to the many careful observers documenting invasions in many local areas, is that such examples occur almost everywhere; that all of the local examples are manifestations of a global phenomenon.

This AGCI session was designed to go beyond listing invasions and their effects to analyzing what can be done to prevent, control, and manage invasions. To that end, the group included biologists and land managers, people from federal agencies and non-governmental organizations, and an economist and a lawyer.

The discussions and presentations led to a number of points of agreement, and some solid progress towards developing means for coping with invasion. Five major results were:

1. Pathways of invasion

We need to recognize the diversity of pathways by which organisms are introduced to new habitats, and develop strategies that are appropriate for each of those pathways. Many species are introduced deliberately, in hopes of economic gain -- pasture grasses and golden snails fall into this category, as do African bees and the European gypsy moth. Others are deliberately introduced for recreational or aesthetic reasons -- brown trout, aquarium fish, and fountain grass fall into this category (although the scale of the plant nursery and pet trades blur the distinction between economic and aesthetic motivations). Others are accidental (if often predictable) contaminants of other goods -- such as the contaminated seed that brought cheatgrass to North America, the Asian tiger mosquito, or the brown tree snake that has devastated Guam's native birds (Savidge 1987) -- and threatens Hawaii's. Each of these pathways requires different means of control, will run into different sorts of opposition, and offers different opportunities for collaboration with other interests.

Some invasions change the nature of the ecosystem in which all natives survive. In other words, they do not just add players to the game, they change its rules.

2. Variation in consequences of invasion.

We must also recognize that there is substantial variation in the consequences of invasions, both in the likelihood of success of invasions by different species and (as noted above) in the consequences of successful invasions. Sarah Reichard presented a model that predicts the likelihood that a potential woody plant invader would become established in a new area; such a model could be used to screen proposed introductions. It is interesting to note that the most important single predictor of successful invasion is whether or not a species has invaded successfully elsewhere. Clearly a database containing information on invasions worldwide would be a valuable tool for the prevention of future invasions.

3. Techniques for countering invasions.

Once a species has invaded a new area (and appears likely to affect health, wealth, ecosystems, or biological diversity) -- how can it be controlled or eliminated? One answer is "early" -- the chances for successful control are greatest and the costs least early in the invasion process. Many invasions display a lag (apparent or real) between introduction and obvious explosive growth. However, the political and/or bureaucratic machinery for focusing on an invasion often is slow, and the best opportunities slip by. The development of quick-response decision pathways and control teams could help substantially (Hobbs and Humphries in press). A second conclusion was that the development and evaluation of a wider variety of techniques for controlling invasions would be worthwhile. For example, Australia and New Zealand make use of toxicants for controlling introduced mammals to a much greater extent than does the United States. Toxicants have environmental costs, but it is not obvious that these are always greater than those of biological control (generally through the use of additional introduced species) or other approaches.

4. Education about invasions.

Most of us who work with invasions have had the experience of dealing with people who consider any effort at control pointless ("invasions are inevitable"), wrong-headed ("oh, so now there are politically correct species?"), or reactionary ("and I bet you believe in shooting illegal aliens on sight, too"). Education about invasions, the threats they pose to native organisms and ecosystems, and the values of those native organisms and ecosystems themselves, are the only effective way to counter those sentiments. There are some notable successes -- many Floridians now understand the threat posed by plant invasions there -- but this awareness took considerable time and effort to develop.

5. Invasions and the law.

Invasion pressure on aquatic sustems is substantial- from aquarium fish dumped into culverts to multimillion dollar efforts to establish sportsfisheries using introduced species.

After substantial discussion of legal and political aspects of biological invasion, we decided that it would be interesting and rewarding to draft a model law outlining how we believe any society should deal with exotic species. The current draft of the law is included later in this report. It is in the format of a U.S. law, but it draws on elements of proposed and actual laws and regulations in Australia and New Zealand, and it is meant to be sufficiently generic to be applicable anywhere.

Overall, almost everyone in the group had spent years of work on some aspect of biological invasions, but even we were impressed anew by the pervasive nature of this global change, and cheered by the possibility that enough diverse groups of people are interested in the phenomenon so that we may at last be able to address aspects of the problem -- in research, management, and political action -- that have long seemed out of reach.

What do we want to come out of this session? We want to educate each other about what is involved and how to effectively take information from these fields into political processes. We want to take the opportunity to resolve some issues such as the use of biological control of invasive species in natural systems and proposals to use exotic species for biological control of native "pest" species. We need more action politically; what strategy should we be pursuing? Should we fight exotics aggressively, do triage (differentiate between those we can't fight, those we can fight and win, and those that don't matter), blockade, or get used to it cause its going to happen anyway? How should we conceptualize and activate our approach to invasions? Thinking longer term, 200 years in the future, if the biological invasion problem was solved: How could this happen? What is the solution? In thinking about how to get from here to there, it helps to know what "there" looks like.

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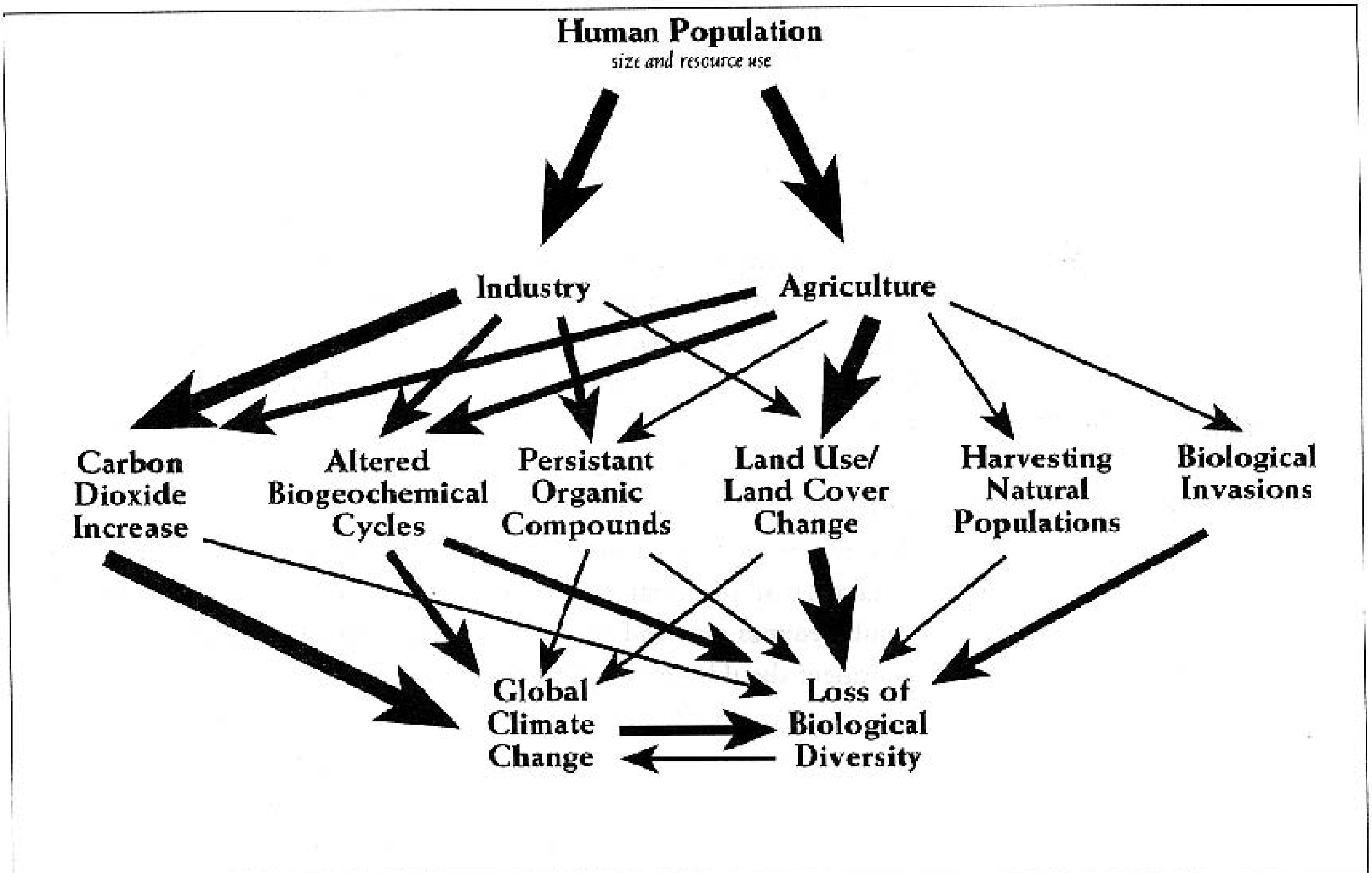

Figure ii.1. Components of global environmental change. Growth in the size of and resource use by the human population is expressed through growing industrial and agricultural activities. These have caused a set of relatively well-documented global environmental changes (well-documented both in the sense that they are occurring, and in that they are human-caused), including increasing concentrations of carbon dioxide in the atmosphere, the production and distribution of novel and persistent compounds such as chlorofluorocarbons (with their attendant effects on stratospheric ozone) and PCBs, global-scale alteration of the biogeochemical cycles of nitrogen, sulfur, and other elements, changes in land use and land cover, the removal of top predators from most terrestrial and many marine ecosystems, and biological invasions by exotic species. These components of change interact; also they will drive changes in global climate, and losses of biological diversity. After Vitousek (1994).

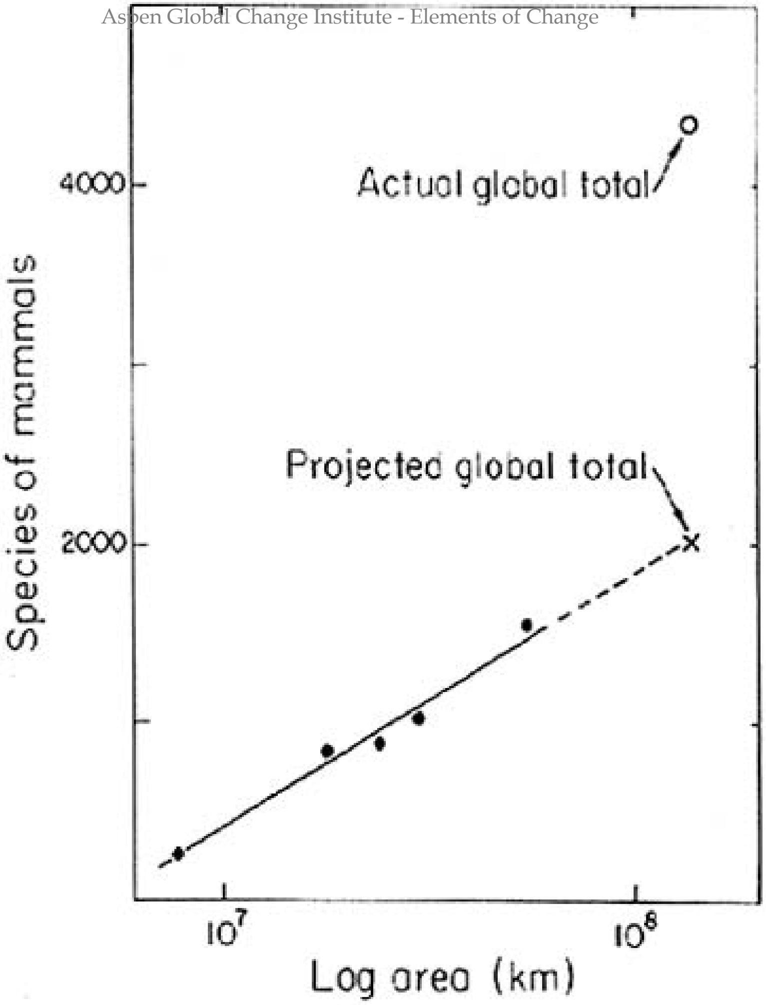

Figure ii.2. A species/area curve for mammals. The number of species on a continent is tightly correlated with the size of that continent — but extrapolating that relationship to the land area of Earth (reuniting Gondawanaland) yields less than half the total number of species that actually occur on these continents. Much of the diversity of mammalian species globally is due to the isolation of separate biotic regions. From a suggestion by Westbrooks (personal communication), analyzed by A. Launer of the Center for Conservation Biology, Stanford University.

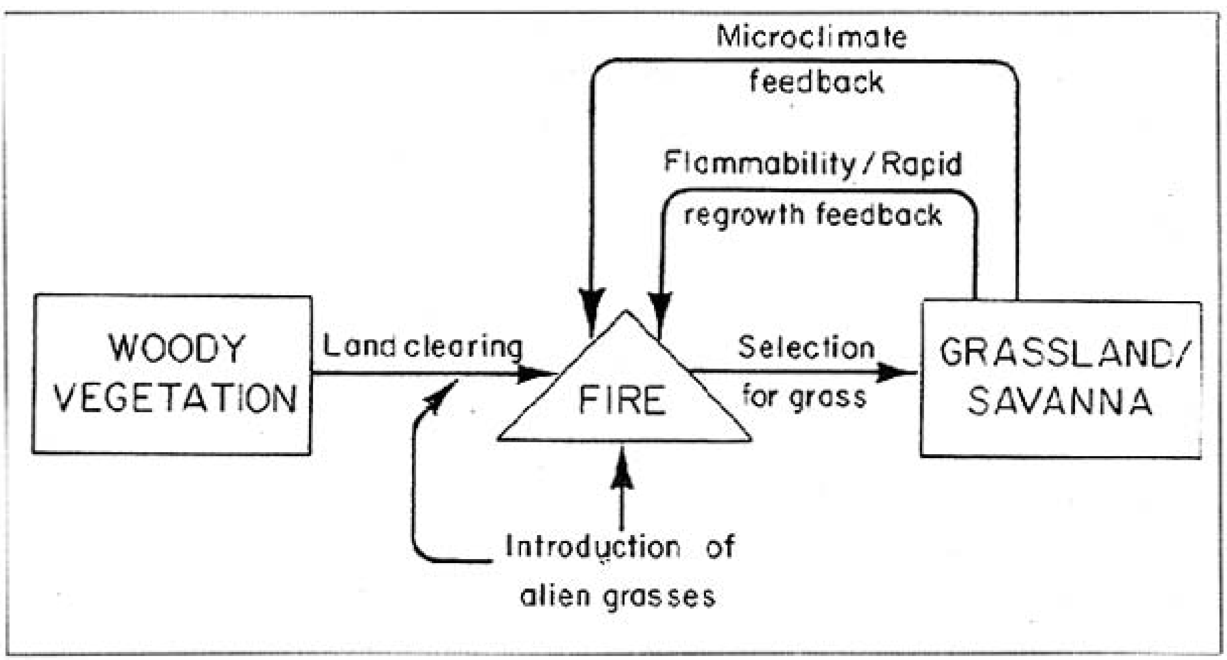

Figure ii.3. Grass invasion and the grass-fire feedback. Land clearing and grass introductions act synergistically to convert forest to grassland or savanna; once conversion has occurred, two feedbacks operate to maintain grass dominance. The hot, dry, windy microclimate of grasslands, and the inherent flammability of grasses favor fire, and the rapid regrowth of grasses following fire keeps communities fire-prone. From D'Antonio and Vitousek (1992).

Ecosystem Management & Legal Strategies to Maintain Ecosystem Integrity

Greg Aplet

The Wilderness Society
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The concept of ecosystem management arose out of the recognition that we have not been very successful at maintaining our ecosystem as we exploit it. The question is how to meet our needs without destroying our ecosystem.

The question is how to meet our needs without destroying our ecosystem.

Five principles of ecosystem management:

1. complexity (all parts are interconnected through ecological processes)
2. change (change occurs constantly in response to key processes)
3. scale (ecosystems exist at all scales; large systems consist of smaller ones, ecological processes occur at various rates)
4. uncertainty (complexity assures surprises, chance events; changing public values are another source of uncertainty)
5. humans as part of ecosystems (we affect and are affected by ecosystems; all aspects of our lives are influenced by the quality of ecosystems)

We have reached a point at which there is a coalescence of a number of key issues around one central theme: the protection of ecosystem integrity.

- biological invasions (protection from species additions)
- classical biological control (damage control)
- endangered species (protection from species loss)
- global change (slowing the rate of change)
- ecosystem management (protecting ecosystem integrity while meeting peoples' needs)

Federal Policy and Plant Invasions

Faith Campbell

Natural Resources Defense Council
Washington, DC

Broad statutes have not proven to be workable in practice.

Dr. Campbell's work involves plant conservation and government policy. She is particularly concerned about invasions by exotic plants into natural ecosystems. Campbell says that the US government wants scientific certainty before it defines what actions should be taken at both the policy and local site levels. The key issues are predictability, understanding the stages of invasions, and how things get out of control.

The government needs certainty because:

a. interest groups (plant nurseries, the pet industry, etc.) are negatively effected by increased restrictions on biota shipments between states and imports/exports;
b. the budget deficit makes Congress wary of spending money;
c. there is a basic inability to understand this issue, and bureaucratic inertia exists.

Do we need new legislation in this area, or would amendments to and/or better enforcement of existing legislation be sufficient? One possible course of action would be to amend the Federal Noxious Weed Act. Such an amendment could become a title of the farm bill. The Animal and Plant Health Inspection Service (APHIS) wants to amend the Noxious Weed Act to cover weeds spreading into natural areas, not just agricultural lands - a new view. Broad statutes have not proven to be workable in practice. The Aquatic Nuisance Species Act is very broad, and currently, not very effective. It involves many agencies that donÕt communicate effectively with each other and includes no money for the agencies to carry out their charges. The zebra mussel was the hot issue of the day in states represented by powerful members of Congress, so the Act passed, but itÕs not a particularly effective piece of legislation.

Biological Invasions in New Zealand

Mick Clout

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New Zealand may be the place on Earth that has had the greatest impact from alien species. This pervasive influence is evidenced by the fact that 43% of all New ZealandÕs flora are now alien to the country. Of all the land mammals currently living in New Zealand, 34 species are aliens and only 2 are natives. Through browsing (grazing) and predation, these invading mammals have made huge changes to natural ecosystems. Faced with this dire situation, New Zealand has undertaken an aggressive set of responses for dealing with invaders.

Of all the land mammels currently living in New Zealand, 34 species are aliens and only 2 are natives.

One distinctive New Zealand native animal which is endangered by exotic invaders is the flightless takahe. There are only about 150 individuals left. Other native species of flightless birds have also been decimated by cats, rats, and other exotic land mammals. A particularly troublesome invader in New Zealand is the possum which kills native trees, changing the composition of forests. Methods of controlling possums include trapping and dropping poison pellets containing the chemical “1080” from aircraft.

The Polynesian rat has had massive effects on small fauna and has traditionally been very hard to control. Recently, however, it has proven possible to eradicate this and other rats on islands. Several New Zealand islands have been cleared of rats through aerial distribution of anti-coagulant poison baits. This has been proven effective on islands up to 250 hectares and is scheduled for trials on islands up to 3000 hectares.

A new organization, the Invasive Species Specialist Group (ISSG), is being set up by the Species Survival Commission of IUCN to identify appropriate actions to deal with invasive species worldwide. Their mission is to reduce threats posed by invasive species to natural ecosystems and native species. Sub-groups are planned to focus on terrestrial weeds, water weeds, fish, invertebrates, marine invaders, microorganisms, etc. Proposed ISSG projects include a newsletter- style publication to promote current awareness, a global database of invasive species, workshops and conferences, technical reports, and information pamphlets for local use.

Feral Animals as Biological Invaders

Bruce Coblentz

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Feral herbivores can totally strip areas by foraging, resulting in severe erosion and subsequent loss of native trees.

Goats and other exotic herbivores (including pigs and burrows) are frequently "ecological dominants" which can alter an ecosystem completely. Feral herbivores can totally strip areas by foraging, resulting in severe erosion and subsequent loss of native trees which die due to lack of soil. One example of such destruction occurs in the Galapagos, on the island of Santiago, where the dense forests provide water to the whole system by dripping fog collected by the trees. As goats destroy this vegetation, the entire ecosystem is destroyed. On Aldabra atoll, endangered tortoises are threatened by goats. And on Hawaii, pigs are dangerous invaders and need to be eliminated to protect the natural ecosystem.

Bruce Coblenz believes that in this country, efforts to control exotic species are often complicated by animal-protection groups that don't want animals destroyed -- even invaders that are destroying native ecosystems.

Invasive Plants and Ecosystem Processes

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Dr. D'Antonio's research focuses on what processes control or limit invasions into natural communities and how ecosystem processes are altered by individual species. One goal of the work is to provide this information to land managers.

Native herbivores can be important at limiting plant invasions. For example, in ice plant (*Carpobrodus edulis*), seedling recruitment is uncommon. Once a plant gets established it becomes a big problem, because of its effects on germination, growth and survival of native species, so it is essential to control it early, at the seedling stage.

Carpobrodus edulis has important effects on soil environment. It causes a substantial decline in pH as well as changes in nitrogen levels and soil micro nutrients. Even two years after eradication, there is still no significant shift back to the original (pre- ice plant) soil conditions. Therefore, if restoration of the native environment is sought, the soil must be altered to promote the return of native vegetation.

In Hawaii, dry forests have been invaded by introduced perennial grasses. These invaders directly effect population dynamics of native species and also have ecosystem effects. One major effect is the promotion of fires. Since grass invasions have taken hold, the frequency and size of fires has increased dramatically. In the region of Hawaii that D'Antonio is studying, a South American grass invades unburned woodland and promotes fire. After fire, another aggressive introduced grass becomes abundant. Native woody components are lost from the system and many areas now look like African savannas.

Since grass invasions have taken hold, the frequency and size of fires has increased dramatically.

In such circumstances, how can native biological diversity be restored? Few native trees and shrubs will germinate under the mats of grasses - the seeds are too small and not enough light penetrates the dense grass layers. Some native community may be created by promoting the few fire and grass tolerant native species, but it is not possible to bring back the original ecosystem.

U. S. Park Service Policy on Exotic Species

John Dennis

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Washington, DC

Management policy is a triage approach, with high priority given to exotic species that have substaaantial impact and can be controlled successfully; little attention to those we can't control or which have little impact.

Congress established the National Park Service (NPS) in 1916 to manage parks to preserve natural and cultural resources for the benefit and enjoyment of the people of the United States. Today, the NPS recognizes that parks are parts of larger regional environments.

National Park Service management policies of 1988, key goals:

- maintain natural environments to evolve with minimal disturbance by humans
- manage natural resources with concern for ecological processes as well as individual species
- in managing parks, maintain all components of naturally evolving systems, including ecosystem integrity
- recognize that exotic (non-native) species are a form of disturbance by humans

Invasions: the good, the bad, and the ugly:

- the good: natural range extensions of native species that occurs naturally -"white hat" species invasion - change is recognized as a natural part of the functioning of natural systems - use locally native species gene pools for restoration.
- the bad: "black hat" exotic invasion that occurs as a result of human action and where introduced species are not natural components of the system - management policy is a triage approach, with high priority given to exotic species that have substantial impact and can be controlled successfully; little attention to those we can't control or which have little impact.
- the ugly: "gray hat" species native to bioregion but not native to park itself; interference with natural processes is allowed to restore past invasion damage - try to attain approximation of natural system if actual restoration is not possible. And some of these can be used to control exotic species.

Questions that arise when trying to manage parks from this policy bible:

- Is the policy scientifically valid and can it realistically be achieved?
- What are "natural processes"?
- What scales are important?
- What elements of biodiversity are important?
- Can we recognize and help the good species?
- Can we attack the bad?

- Should we pack species into the park?
- Should we help species across fragmentation barriers?
- Should we attempt to anticipate global climate change and relocate species, especially long-lived ones such as certain trees?
- Is it OK to insert more exotics to control other exotics?

Should we attempt to anticipate global cliamte change and relocate species, especially long-lived ones such as certain trees?

Exotic Species in Aquatic Ecosystems

Tom Dudley

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> Aquatic invasive species have gained attention because of the spread of the zebra mussel, an invasion which will require a $2-billion cleanup over the next two years, and up to $10 biollion during this decade.

Aquatic invasive species have gained attention primarily because of the spread of the zebra mussel, an invasion which will require a $2- billion cleanup over the next two years, and up to $10 billion during this decade. Invasions into natural habitats is the focus of Dr. Dudley's work. The zebra mussel is primarily a problem in "disturbed" systems as opposed to "natural" ecosystems. This raises the question: is there really a clear separation between natural and modified systems? The distinction is actually quite arbitrary because important natural elements, for example, some endangered species, may be present and threatened in systems that have been quite modified by humans.

Some examples of problem aquatic invaders:

- Introduced bass have left lakes of introduction and gone into the larger system, particularly into more pristine upstream areas.
- A great deal of money goes into habitat improvement for the brown trout, an introduced fish from Europe which preys on native species.
- Rainbow trout have been introduced to more habitats than the Monterey pine.
- The bullfrog was brought to the western US from the eastern US to supply frog leg meat and may have eliminated some populations of native frogs.
- Beaver have been stocked extensively beyond their natural ranges in the Sierra Nevada. They occurred naturally up to about 5,000 feet in the Sierra Nevada and are now up to 9,000 feet (although in their native areas, they are at higher than natural elevation; they can thus change the ecosystem dramatically); in parts of the Great Basin, beaver are used for restoration because their dams can trap sediments and reduce erosion.
- Nutria were brought in for fur and became a harmful invader by burrowing into levees.
- Chinese common carp is a problem invader in many parts of the US, especially the Mid-West.
- There have been many intentional introductions of vertebrates, especially fish, from North American sources rather than foreign; a high proportion of these are dominant predators in their native habitats.

Impacts

1 Species/Populations

At this level, exotic organisms can endanger a species' existence and/or reduce populations. One example of a species/population level impact is genetic introgression from stocked trout

populations which hybridize with natives, diluting their genetic integrity. In one case, there may be no natural population of true native lahontan cutthroat trout; the only true lahontan cutthroat populations have been bred and introduced into fishless waters for their protection. Similarly, hybridization has resulted in the loss of genetic individuality in crayfish populations, for instance, the threatened Shasta crayfish. Aquarium fish introduced into springs are major competitors and predators threatening native desert spring fish and western trout.

Native golden trout are endemic to the Kern River watershed in California and are severely threatened by introduced brown trout. An aggressive, multi-million dollar eradication program has nearly eliminated brown trout in the Kern river system. The program consists of electroshocking (which stuns but doesn't kill the fish), followed by application of a chemical treatment, and finally, replacement of only golden trout. To keep migrant brown trout from coming back into the system, rock structures like waterfalls are built to prevent fish from coming back upstream. By starting at the headwater and moving downstream, the project seeks to create a stream network free of brown trout. So far, the program appears to be successful at eliminating most brown trout and protecting the only endemic habitat of golden trout, but the presence of stragglers requires periodic retreatment.

The history of trout in the American West is characterized by moving them around in coffee cans. There is almost no river system that has not had non-native trout introduced over the past 100 years or so. The taxonomy of aquatic invertebrates is relatively unknown; there are now low and greatly modified invertebrate communities as a result of all the introduced trout. Introduced brook trout and other fish may have eliminated most populations of three species of frogs in ponds and streams. Dave Bradford's work on mountain yellow- legged frogs suggests that trout introductions are the major factor in frog loss, while disease and drought (which dries out satellite populations in shallower ponds) are other factors. There is only a handful of surviving populations of this frog species. They are near extinction and may have lost some genetic variability. One program is using seining (nets) to remove brook trout and then will reintroduce frogs to these ponds.

Introduced brook trout and other fish may have eliminated most populations of three species of frogs in ponds and streams.

Non-indigenous species are largely responsible for threatening native species with extinction: about 58% of listed fish species are documented as threatened by exotics, while 15% of protected bird populations are threatened by exotics. Two-thirds of all endangered species face exotics as a major threat. Aquatic habitats function similarly to islands, where exotics are also a major threat; similarities include discrete environmental boundaries, more limited habitat, fewer refuges from exotic invaders, and high dispersal abilities of non-indigenous species. Populations in confined areas tend to be more susceptible to exotic threats and local extinctions than populations that are distributed over larger and more heterogeneous habitat.

2 Communities

Nile perch were introduced into Lake Victoria in Africa as a food source and ended up eliminating about 200 species of native cyclid fishes. Two-thirds of the species of cyclids once found in the lake are now gone and this percentage is rising rapidly as Nile perch spread throughout the system. Nile perch now make up about 80% of the fish biomass in Lake Victoria. The perch yield only one-third the price per pound of the native cyclids, so the impacts have been enormous on all levels Ð biological, ecological, economic, and sociological. Fishing communities have collapsed and been replaced by large industry which can take advantage of the harvest-to- harvest nile perch. In addition, the native cyclids can be air dried for storage whereas perch can not, and so are usually smoked, leading to clearing of land for firewood, resulting in erosion and other environmental damage. This species introduction clearly has

caused cascading effects through the entire socio-bio-ecosystem in just ten years, roughly from 1980 to 1990. In general, introduced fish can have extraordinary effects in a system because they often can quickly become dominant species in the communities.

3 Ecosystems An example of ecosystem impacts is the introduction of Bermuda Grass to the southeastern US for cattle forage, lawns and livestock feed. It makes a carpet on the stream bottom and increases the resistance of substrate to disturbance during floods, eliminating the scoured habitat preferred by native fish and invertebrates (a clean sand substrate that provides the spawning area for native fish). This also creates habitat for the fathead minnow and other exotic fish that compete with natives, and facilitates establishment of watercress, aquatic buttercups and other weedy vegetation. The result is a short-circuit of the natural successional process which sets up what we label an “invasion complex” in which one invading species favors additional invaders. It doesn’t work to look only at single species Ñ they can act in synergy with other invaders in a manner similar to the synergism of two “safe” chemicals which can interact to become toxic.

Two-thirds of all endangered species face exotics as a major threat.

Another example of ecosystem impacts is invasion by tamarisk, a tree found in Southwestern US riparian areas, which results in a series of effects on an ecosystem. Tamarisk is effective at picking up salts from the soil and depositing them on the surface by dropping leaves. This duff on the substrate makes it difficult for anything to establish under it and insects and birds decline for lack of habitat and food resources. Tamarisk is dependent on disturbance to get established; seeds are deposited on banks and grow rapidly. Until it matures, tamarisk is not tolerant of flooding and so thrives in controlled (dammed) systems which eliminate natural flood cycles. On Sycamore Creek in Arizona, numerous young cottonwood saplings survived a larger-than-normal flood, while very few tamarisk survived this natural disturbance agent. Similarly, flooding of Coyote Creek in southern California killed 63% of tamarisk plants present and only 14% of the native riparian trees. As flood frequency decreases, and trees can grow to a larger size, tamarisk become more resistant to the occasional floods and can take over.

This raises the issue of global climate change and how a predicted drier western US could favor expansion of exotics over natives. More variability in rain events and longer droughts may provide a longer window of opportunity for trees like tamarisk to establish and attain resistant size. Also, as water becomes ever scarcer, currently unregulated streams may become dammed and regulated and thus made susceptible to invasion by tamarisk.

In the research of Sarah Kupperburg in California, she found that bullfrog populations increase and native red-legged frogs decrease during drought periods and the reverse occurs during higher flow periods. Longer periods without flooding also tend to favor development of silty, slower stream habitats that favor transplanted Eastern fish species over native Western species. Several biologists have suggested that by using flow releases from reservoirs, especially short-period high-volume releases to scour stream channels, we could reduce habitat for exotics and maintain the type of habitat needed by natives. Can we use flow management in this way as a tool for protecting native species of both flora and fauna? In general, change in the natural disturbance regime favors establishment of exotics. Flooding at least once every four years appears to be necessary to prevent the establishment of tamarisk. An interesting direction for future research is to examine ways in which we can manipulate altered ecosystems to retain the important elements of natural disturbances.

Ecosystem management approaches for aquatic systems

We need to look at the problem of non-indigenous wetland species from a watershed perspective. Jurisdictional boundaries are inappropriate ways to organize our approaches to ecosystem problems because there are many interacting downstream impacts of upstream actions. The Natural Communities Planning Program in the San Diego region is an example of an eco-regional approach. Instead of fighting battles spot by spot, they have backed off, looked at a map, and are attempting to determine areas suitable for protection or development, and what species are involved. Another example is Aquatic Diversity Management Areas (ADMA), promoted by fish ecologist Peter Moyle, which are based on identifying important co- occurring groups of species, rather than focussing only on single- species management, and concentrating protection on certain key representative areas of each multi-species assemblage as a form of triage which directs efforts efficiently to protect the maximum representation of our natural heritage.

In general, change in the natural disturbance regime favors establishment of exotics.

How to use limited resources in the context of improved environmental protection is an important management question. Environmental groups worry about shifting control to regional councils, as is being encouraged by Secretary of the Interior Bruce Babbitt, because when local groups control the planning process, their track record for environmental protection is not that good. Local groups interests are often influenced by local development pressures. Furthermore, national interest must be represented in decision-making at the local level. The Endangered Species Act (ESA) is an effective tool for promoting national interest. Some believe the ESA's emphasis on single species has siphoned off money, attention and interest from a real ecosystem management approach, stressing single species protection instead of natural community and unique habitat protection. Others feel that plants get short shrift as we put the majority of our resources into a few mammal species, although some of the more spectacular cases of radical single-species protection involve rare plant genotypes. We also tend to throw a lot of money into highly degraded areas that perhaps should be written off and the focus shifted to preserving more intact ecosystems. The ADMA system has five categories based on degree of degradation and gives each a different level or process of protection. Dudley again emphasized the distinction between protecting terrestrial and aquatic systems. For aquatic systems, we absolutely must take a watershed approach or management efforts cannot work, due to the extremely interconnected relationships in these systems. With terrestrial systems, it is sometimes possible to take a smaller area and protect it. However, we should bear in mind that in most cases, aquatic and terrestrial ecosystems cannot truly be considered independently from each other.

General Patterns of Aquatic Invasions:

- Intentional, maintained introductions are common
- Predation especially common with vertebrates
- Connectedness of aquatic systems leads to rapid dispersal
- Inverse relationship with natural disturbance, in that altering natural disturbance regimes in any direction fosters exotic invasions

Some specific examples of aquatic system invasions in the Western US:

- Sycamore Creek in the Sonora desert: invaders include Bermuda grass, fathead minnow, red shiner, tamarisk; effects of livestock grazing (promote growth of

Bermuda grass, etc.); there is no desert stream fish that is not endangered at this point.

- Anza-Borrego State Park in the Colorado desert: invaders include procambarus (an opportunistic crayfish which has out- competed or preyed on other aquatic fauna and eaten natural vegetation, altering the stream bottom completely), tamarisk, bullfrogs (which endanger other amphibians as well as other animal species).
- Kern River in the Sierra Nevada (the only endemic river for California golden trout): invaders include brown trout, rainbow trout, tamarisk, sagebrush (which is native to the region, but is expanding into previously-wet meadows); livestock grazing is a problem, and is also implicated in many other invasions.

For aquatic systems, we absolutely must take a watershed approach or management efforts cannot work, due to the extremely interconnected relationships in theses systems.

Coastal California streams in the chaparral: native steelhead trout are threatened by genetic introgression from stocked rainbow trout populations; red legged and yellow legged frogs are endangered by bullfrogs and fish; invasions by sunfish (predators that also disrupt the stream bottom), Asian clam, arundo (giant reed), ivy, blackberry, etc. These streams are also threatened by water diversions, stocking of sport fish, development pressures, land use, and sedimentation, all of which are factors that interact to exacerbate invasions by non-native species and hasten the decline of native species.

Lessons Learned in Plant Invasions

John Ewel
University of Florida, Department of Botany
Gainesville, Florida

Lessons learned from early work with invaders

- Intact communities are not only more resistant to invasion, but some are, in fact, non-invasible.
- Subtle changes in regional hydrology increase the vulnerability of otherwise resistant ecosystems to invasions.
- Fuel loads produced by invaders, and the flammability of invaders, can divert succession.
- Native species often form strong and essential biotic links with aliens (e.g. pollination, dispersal, scarification).

Intact communities are not only more resistatn to invasion, but some are, in fact, non-invasible.

Lessons from self-designed seeded tropical successive communities

- More diversity is not necessarily better with respect to rates of loss of leaf tissue, plant productivity, and nutrient loss via leaching.
- Some patches of a single species are more invasion-resistant than are diverse mixtures.
- Big divisions are those that take place on the life-form level.
- Move toward greater simplicity in research. Use simple plantations of fast-growing plants; one or two life forms in a non- constraining environment.

Early outcomes

- Successful dominants preclude invasion, even when grown in monospecific stands.
- In most cases, light availability is more important than nutrient availability in controlling invasions.
- Stands of trees that demand lots of both light and nitrogen are vulnerable to invasion if below ground competition is reduced.
- Site invasion may be high initially, then very low, then somewhat higher (due to changing light and shade from canopy).
- Alien plant species now outnumber natives in Hawaii.
    - The pig (an invasive species) is considered sacred by a substantial portion of the community, so control efforts must consider cultural factors.

Biological Invasions in Wetlands

Katherine Ewel
USDA Forest Service, Institute of Pacific Islands Forestry
Honolulu, Hawaii

The common practice of draining wetlands has frequently opened up avenues for invasion.

Dr. Ewel described the relationship between an exotic herbivorous fish and hydrilla, which is an invasive aquatic weed that is widespread in the southern United States. She constructed a model to simulate the effect on a lake ecosystem of using this fish as a biological control agent.

Her current research interests are concentrated in wetlands. The characteristic elements of wetlands are hydroperiod (length of flooding), flow rate, water quality, and fire frequency. Management practices that affect these elements can therefore change the species richness and productivity of wetland ecosystems. When a wetland is used for wastewater recycling, for instance, the increased nutrient supply may combine with the longer hydroperiod to alter both plant and animal communities. Draining a wetland, both by constructing berms to reduce water inflow and by building canals to speed water outflow, also changes the plant community; this common practice has frequently opened up avenues for invasion by both native and alien species.

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Education and Biological Invasions

Bill Hammond
Natural Context, President and Environmental Education Manager
Fort Meyers, Florida

What is natural? Is a building natural? Most people's initial reaction is no. But isn't a bird's nest natural? When we say nature is "out there" but not in here, we are saying that we are not natural; this separates us from nature and creates a dichotomy. Most people don't know where their milk comes from; they have no concept of "cowness." In general, people have no concept of, or experience base with, wildness; the average person [in U. S.] spends only 5% of his or her time outdoors. So how do we raise the consciousness of people about biodiversity and invading species? The key is getting people of all ages engaged in the environment - immersed in learning. Don't try to teach anything at first; after people experience the environment, they'll collect data, they'll give it to those who need it, they'll write about it, etc. All we have to do is provide a link and incidental learning happens.

In general, people have no concept of, or experience base with, wildness; the average person [in U.S.] spends only 5% of his or time outdoors.

Engage school children in real planning decisions; help them to have a stake in such decisions. They need to understand not only the biology, but also the economics; so, for example, have them run a business. They can find out how to create a sustainable butterfly garden, for example. Students have demonstrated the ability to collect real data - they do it every day. Teach responsibility. Do service projects (give them a chance to be altruistic; this is unusual in our current society). Time for reflection is important too: "don't just do something - sit there". And when people do something themselves, they have ownership of it and responsibility for it.

These are the fundamentals: Energy flows and matter cycles. Basic systems are interacting components forming a web. History is patterns of the past. Environment education is patterns of the environment and how they interact.

There is a distinction between a problem and an issue: problems are data based; they become issues when there are values involved. An issue always starts as a problem and then values make it an issue. How are people moved from awareness to action.? Awareness, understanding, and action are a progression.

Different values create different outcomes. For example, in the past, we altered rivers to make them do what we wanted; now we are changing rivers back to their original form.

What can school children do? In Florida, school children managed to get the government to purchase and protect a swamp. They did everything from the biological inventory to getting the ordinance passed (through 23 drafts and 19 public hearings). Children also take part in "melalueca pulls"; they can pull up an acre of these invading trees in a lunch break if the soil is very wet or very dry. They're not "bad" trees, they're just in the wrong place. You've got to do things in order to learn. The students doing the melaleuca pulls learned from their mistakes and are now quite effective.

Miscellaneous thoughts: Get students to act things out. Try teaching the krebs cycle with students acting out the steps as a ballet. People come to understand the patterns of things by experiencing them . We should learn *with* technology, not *from* it - it's just a set of tools. When creating an educational program, we need to appeal to different learning styles. Mentorship is the most powerful role you can play. Pick out one kid and follow up, make contact. A mentor is one who moves into your life and opens doors for you. Ambiguity is usually left out - specificity is the key in our conventional education system, but the other half of the assignment is the ambiguity - like "tree-ness." If you want to succeed, you'd better work with others .

Start with data and move up the list to information, knowledge, understanding, and finally, wisdom. Wisdom comes from deep knowledge and has transferred understanding.

Children take part in "melalueca pulls"; they can pull up an acre of these invading trees in a lunch break if the soil is very wet or very dry.

Theories toward action:

Information will empower you to act.

Learning how to do things will empower you to act.

Engaging in action empowers people.

When people feel bonded to nature, they will act to protect it.

Start by building the contextual connection - the "why."

Then give the content in films, lectures, slide shows - the "what."

Then get to the "how" - the action component - try it out.

Then "if" - how can you use this in another way?

On dealing with invasive species, we can engage the public by publishing "hit lists" and popular magazine articles, as well as technical papers. And we need science that will stand up to the scrutiny of special interests in court.

What Makes an Area Invasible?

Richard Hobbs
CSIRO, Wildlife and Ecology
Scotland, United Kingdom

We need a mechanism to recognize, in the early stages, what species are going to be successful invaders. For example, *Mimosa pigra* sat around in a "lag phase" for 100 years, from 1880- 1980, and then its population exploded exponentially. Actually, it was increasing within certain areas for a couple of decades, but on the large scale, there was a sudden and dramatic leap. Do plant species build up "cumulative populations" during lag phases and then "triggers" allow for the explosion? Are lag phases a significant phenomenon or is it just the way we monitor and measure the growth that makes it look like an explosion, when really it was growing exponentially within the original patch all the while? This is partially a spatial question - is it growing exponentially within the one patch?

There seems to be consensus among this group that any time you see an exotic plant that has established a new population, and that species has a history of being a successful invader elsewhere, you should move to control or eradicate it before it becomes a major problem.

Australia has 222 species of noxious weeds and another 1500 other non-indigenous species to deal with. They can't respond to everything with a chainsaw. They need to monitor growth within the original patch, and if they see exponential growth, they can move to control it. Some feel they should control it sooner ("monitor it with a chainsaw"). What if the original patch was in a suboptimal environment and so may not have grown exponentially for that reason? What are the triggers for exponential growth - chance flood events, etc.?

The message to policymakers is that you need to monitor more carefully and manage invasions earlier. You should look for exponential growth within a population or the establishment of a second population elsewhere. Rapid deployment of resources is key to the ability to control an invasion.

Characteristics of an area that is susceptible to invasion:

- In general, *disturbed* areas are more invasible than undisturbed areas. There is a difference between natural and human disturbances, as well as differences in degrees of disturbance. (For example, grazed land tends to be invaded much more easily than ungrazed land.) There are also synergisms among different kinds of disturbances that allow invasions to take hold.
- *Fragmentation* of natural habitat makes an area vulnerable to invasion; edges of natural habitats are especially vulnerable.

The message to policymakers is that you need to monitor more carefully and manage invasions earlier. Rapid deployment of resources is key to the ability to control and invasion.

- *Human activities* modifying ecosystems cause most of the problems. There are also public perception problems - if people like a particular plant, they don't want to get rid of it.

In order to prioritize limited resources, we can characterize areas as high or low value, and as high or low disturbance, yielding four boxes. The strategy for each of these four boxes is different:

High value, low disturbance areas: protect and keep invaders out;

High value, high disturbance: try to control invaders;

Low value, low disturbance: do nothing;

Low value, high disturbance: let them go, we can't do everything with limited resources.

"Shocking, how easily we have lost a world that seemed so stable and safe."

Management actions required, in this order are:

- quarantine,
- prevention,
- detection and early control,
- eradication,
- integrated ecosystem management.

Conclusions

- The current emphasis is on control measures implemented once a species has become a major problem. An integrated program of prevention, detection, early control and ecosystem management carried out at all stages of the invasion process is required.
- Changes in emphasis from control to prevention, and from control of individual species to ecosystem management are required.
- Research on plant invasions needs to be directed at elucidating the linkages between disturbances and invasions and at sorting out causal relationships. Research is also needed on the ecosystem impacts of invasions.
- Much of the plant invasion problem stems from socioeconomic, rather than ecological, factors. Attempts to treat weed invasion problems will fail unless the underlying causes of the problem are identified and dealt with.
- A rational framework for setting management objectives and priorities has to be adopted. This can be based on the relative value of different areas (in terms of conservation or production) and the relative likelihood of successful prevention or control. Weed problems are too numerous, too extensive, and too pervasive to allow dissipative use of resources through ad hoc decisions.

Plant invasions are a major threat to biodiversity worldwide. Unless conservation biologists, land managers, and policy makers respond to the problem now, we face a world dominated by a small aggressive fraction of the world's plant species.

Disturbed areas are more invasible than undisturbed areas. Fragmentation of natural habitat makes and area vulnerable to invasion; edges of natural habitats are especially vulnerable. Human activities modifying ecosystems cause most of the problems.

Discussion Points

Epidemiology models for spread of disease can be used to look at spread and control strategies for exotic plants. Computer models/games can be used as tools to both understand and analyze these phenomena better and to educate people about the realities of invasions. Fire spread models are a good analogy also.

There is a potential fallacy of monitoring until you figure out what to do - the spread is tremendous while you wait for the results of further study, and it is also probably more cost effective to eradicate than to study.

It seems like many invasions are caused by serendipity. For example, the gypsy moth arrived at the North Carolina coast on July 4; since it was a holiday, proper inspection was delayed by two days, leading to an $800 million problem.

An integrated program of prevention, detection, early control and ecosystem management carried out at all stages of the invasion process is required.

Animal Invasions in Australia

Richard Hobbs

CSIRO, Wildlife and Ecology
Scotland, United Kingdom

The first step is to control predators (foxes) with aerial broadcasting of the poisonous chemical "1080". Step two is to reintroduce mammals from islands and set up exclusion zones and buffer zones to keep foxes out.

Australia has an extinction problem similar to New Zealand's. About 30 to 40 species of mammals are either totally gone or restricted to small areas; there have been huge range reductions due to introduced fox, rabbit, and other mammals. When rabbits became a problem, the fox was introduced in an attempt to control them. The fox did little to control rabbits but a lot to kill off small to medium- sized native mammals. There is now an attempt in Western Australia to try to increase the ranges of some these endangered native mammals by breeding and reintroducing populations while controlling predators.

The first step is to control predators (foxes) with aerial broadcasting of the poisonous chemical "1080". In Western Australia this chemical occurs naturally in native plants so native animals aren't effected, while nonnatives are killed. No ecosystem effects have been detected thus far from the use of 1080 in Western Australia, perhaps because it exists naturally in this ecosystem. (1080 cannot be used in areas in which the chemical does not occur naturally or it would kill off native animals as well as invaders.) Step two is to reintroduce mammals from islands and set up exclusion zones and buffer zones to keep foxes out. However, as you control foxes, feral cat populations expand. Cats won't take the poison bait so they haven't yet figured out to control them. Cats harm native animals as well, and there is now a movement to support more wildlife and fewer cats.

Relevant Factors in Plant Invasions

Laura Huenneke
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In Northeast swamp forests, introduced pathogens have eliminated the American elm.

In Hawaii, there has been a strawberry guava invasion. Dr. Huenneke began with two hypotheses: Is establishment of the vigorous invasion by this plant the result of soil disturbance caused by feral pigs? Is establishment by seed, dependent on processing by animals? The answers to both questions turned out to be no.

A number of other factors turned out to be relevant. Natives can't survive being covered by plant litter while nonnatives can survive under litter for years and then send up a shoot through the layer and establish themselves. Breakage is another factor; 27% of natives break and just half of these survive, compared to a 98% survival rate by nonnatives.

In New Mexico, grasses were altered by cows and the vegetation is now much like that of the deserts further south. Invasion of mesquite is accompanied by degradation of soil, formation of dunes, and massive disturbance, but does not seem to be accompanied by pervasive invasions.

There is a native thistle which has hybridized with invader thistle species. The Forest Service is now considering listing this native thistle as a noxious weed. The evolution of weedy behavior in this native thistle is a result of its hybridization with the nonnative varieties. Human impacts may have contributed to the development of this behavior.

The evolution of weedy behavior in this native thistle is a result of its hybridization with the nonnative varieties.

Australia's Policies and Strategies For Non-Indigenous Species

Stella E. Humphries
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The natural environment over much of the continental areas is degraded to various extents through different processes including over-stocking, grazing of marginal country, over clearing, spread of non-indigenous species, and intensive irrigation.

Australia is an isolated, island continent slightly smaller than the continental US. It is sparsely populated and highly urbanized with 60% of the people living in five cities. Seventy-percent of the continental area is arid and the vegetation is characteristically low, open woodlands or shrublands. High rainfall areas are very small; tropical rainforest covers less than 1% of the continental area. A relatively narrow coastal and sub-coastal band in the east and southwest has adequate rainfall to support some tall forest, intensive agriculture and permanent human settlements. Soils are characteristically infertile, shallow, stony and/or salt-prone.

The bulk of the continental area is grazed by sheep and/or cattle. Feral grazers, particularly rabbits whose range has now spread to more than half of the continental area, are a major management problem.

The complement of native plants and animals is unique; Australia has:

- 20,000 taxa of higher plants of which more than 90% are unique to Australia
- 850 species of birds of which 70% are unique to Australia
- 52% of the world's 280 marsupials; 2 of the 3 monotremes
- 700 species of reptiles of which 88% occur nowhere else
- 94% of its frog species which occur nowhere else

Since European settlement:

- about 100 plant species are believed extinct
- a further 1000 are thought to be endangered or vulnerable
- about 20 species of mammals have been lost; most in the last 40-50 years
- 25-78% of vegetation alliances are poorly conserved
- 250 square kilometers of land are lost each year to soil salination
- groundwater levels are rising by more than 20 cm a year, bringing salt to the soil surface

The natural environment over much of the continental area is degraded to various extents through different processes including over-stocking, grazing of marginal country, over clearing, spread of non-indigenous species, and intensive irrigation. The poor record of past management, together with an increasing sense of the uniqueness of Australia's plants, animals and ecology has led to marked changes in the land ethic in the 1990s.

Non-indigenous plants as an environmental threat

Among the greatest threats to Australia's natural communities, apart from land clearing, is the spread of non-indigenous plant species. Almost every major ecosystem has been extensively altered and degradation continues as these species infill and expand their range. Of the 17,000 plant species occurring in Australia, 11% are introduced and about half of these become weeds. A smaller percentage becomes weedy in the natural environment but it only takes one aggressive species to totally destroy an ecosystem.

Most of the major weeds are intentional introductions. Of the 220 species proclaimed noxious, over 50% were brought in deliberately. The majority of these were for ornamental purposes. This is compelling evidence for changing the current screening systems for plant imports, a process now in train. (See Appendix 2, Draft Model Law)

Of the 220 species proclaimed noxious, over 50% were brought in deliberately. Themajority of these were for ornamental purposes.

Broad-scale, single species invasions tend to dominate in the extensive grazing country of northern Australia. Grazing, together with a very different fire management regime, induces drastic direct or indirect changes to the natural ecosystems. Exotic trees and shrubs are now displacing native vegetation over thousands of square kilometers of the semi-arid and monsoonal tropics. Among the more aggressive tree/shrubs are prickly acacia (*Acacia nilotica*), rubber vine (*Cryptostegia grandiflora*) parkinsonia (*Parkinsonia aculeata*), mesquite (*Prosopis spp.*), giant sensitive plant (*Mimosa pigra*). The vast distances, the low human population density, and the low economic value of the land, results in an almost impossible management scenario under current land-use (i.e. grazing) regimes which maintain disturbance.

In the eastern and southwestern parts of the continent, multi-species invasions are the dominant pattern. In these more populated parts of Australia, the vegetation is highly fragmented and thus also vulnerable to invasion, mainly by ornamental species grown locally, and the ubiquitous grasses. The native fragments are often repositories of rare species, being the last vestiges of once more widespread communities. Rainforest communities are typically highly resilient to invasion unless fragmented. Edges become infested with large numbers of sun-loving exotic vines (e.g. *Thunbergia grandiflora*, *Cardiospermum grandiflorum*,), creepers (e.g. *Tradescantia albiflora*), shrubs (e.g. *Lantana camara*, *Ligustrum lucidum*) and grasses (e.g. *Melinis minutiflora*).

Some of the more invasion resistant ecosystems appear to be the intact areas of rain and temperate forests, mangroves, the alpine vegetation and red sand deserts.

Grasses are particularly insidious weeds. They are pervasive, are next to impossible to control, and their ecological effect is often indirect through changed fire behavior, or it is subtle, such as through the choking out of regenerating native species. Grasses have been introduced to most parts of Australia and there is now a current and unresolved debate as to how to manage the inherent conflict between producers who want to introduce more species, and the conservationists who wish to protect natural systems from further invasion by new species.

A review of environmental impacts of non-indigenous plants in Australia can be found in Humphries et al. (1991, 1995).

Government responses to the problems of non-indigenous species

Marked attitudinal changes have taken place in Australian society in the 1990s toward greater awareness of ecological imperatives and the need for limits to resource exploitation and more active conservation. This is reflected in new government policy initiatives and in the implicit or explicit adoption of four major principles which underlie them:

- ecologically sustainable development
- conservation of biodiversity
- treating causes and not symptoms
- cross-sectoral cooperation
- community empowerment

Grasses are particularly insidious weeds. They are pervasive, are next to impossible to control, and their ecologicall effect is often indirect through changed fire behavior

Federal actions to address the newly emerging ethics of the 1990s regarding resource use, land management and conservation include restructuring of institutional arrangements, a plethora of strategies, legislative reviews, and funding of new programs.

A number of levels of government are responsible for various aspects of non-indigenous species in Australia: Commonwealth, State, Local, and Sectoral. Constitutionally, non-indigenous species are a state responsibility except when they are involved with import, are on federal land, impact national initiatives or facilitation of change, where market forces do not give the desired outcome, or when community ownership issues are involved. The federal government has instituted agreements to bring state policy in line with its own.

Key federal strategies that are relevant to non-indigenous species management include:

- Decade of Landcare (1991) acknowledges the need to take stock of current practices in land management and to foster change.
- National Strategy for Ecologically Sustainable Development (1992) recognizes the need for sustainable use and management of natural resources.
- National Strategy for the Conservation of Australia's Biological Diversity (in draft) recognizes the impact of non-indigenous plants and animals on biodiversity and the maintenance of ecosystem processes.
- National Strategy for Endangered Species (1992) has provisions to protect endangered species including from threat by non- indigenous species.
- Vertebrate Pest Strategy (1993)
- National Weeds Strategy (1995)

The Decade of Landcare is a program worthy of note because of its extent, its bottom-up approach and its immense and growing success. It is a community-level program coordinated and funded by the federal government. It brings together the range of regional and local interests to address various aspects of land management from soil erosion to tree planting to pest control and catchment management. Funding is provided to local groups through a competitive grant scheme for projects which fall within the guidelines. The small cell social structure that has developed through Landcare across Australia has important spin-offs for integrating new initiatives which further augments the community power base.

The fund (a total of $105 million in 1993-94) is distributed among a number of programs within which aspects of non-indigenous species management could be funded: $14 million for community Landcare activities; $12 million for land management and sustainable agriculture projects; $10 million for catchment management projects; $2.3 million for "Save the Bush" program; $4.3 million for the "One Billion Trees" program.

The Endangered Species Program, funded at $4.3 million in 1992-93, provides for research and surveys, recovery plans, and threat abatement plans relating to protection of endangered species from any threatening processes, including non-indigenous species.

The Feral Pest Program was funded at $2.2 million in 1992-93. The main feral animals are the rabbit, fox, goat, pig, and horse.

Australia's National Weeds Strategy

The development of the Australian National Weeds Strategy began in 1992 in response to an unprecedentedly large ad hoc request to the federal government for the control of a single species - Mimosa pigra. The species had, in just a few years, invaded, to the exclusion of the native community, large areas of flood plain near Darwin, in the Northern Territory. Its rapid growth and its potential to spread to the adjacent river flood plains of the Kakadu World Heritage Area and to the remainder of northern Australia's rivers called for an immediate response. However, the government wanted rationalization of future funding priorities. Weeds such as mimosa fell outside the charter of the usual administrative processes set up primarily for agricultural weeds and outside the funding capabilities of state conservation agencies.

The Decade of Landcare is a program worthy of note beacause of its extent, its bottom-up approach and its immense and growing success.

The Strategy was completed in 1994 under the auspices of the Standing Committee on Agriculture and in 1995 is in the process of review by the production, conservation and forestry portfolios. Funding and administrative arrangements within the federal government are still being decided.

The linkages between human activity and invasion by non- indigenous species have been recognized increasingly by land managers and policy makers. The scale of the weed problem dictates that direct control by mechanical and chemical means can be effective only at a local and possibly regional scale. An integrated management approach is the only strategy with some long-term possibility of success. Prevention, judicious and limited application of direct control and an emphasis on appropriate land use and sustainable land management practices are foundation principles for the Strategy.

Some specific features of the Strategy include:

- a public consultation process clarified the fact that the spread of non-indigenous plants was considered a major threat to biodiversity and to the integrity of native ecosystems across Australia. The message from the public that emerged from this process was so consistent that it marked a shift in government thinking and priorities in relation to weeds.
- the principles relating to Ecologically Sustainable Development are explicitly adopted in the Strategy.
- historical emphasis on individual species control has shifted toward

consideration of integrated land management principles for both preventative and rehabilitation measures.

- addressing root causes of weed spread (e.g. over-grazing) is emphasized by contrast to treating only the symptoms (the weeds).
- prevention and early eradication are considered the most cost- effective management tools.
- new plant import screening procedures were developed and administrative procedures put in place for joint administration under the Quarantine Act (1908), aimed at health and production, and the Wildlife Protection Act (1982), aimed at protecting the environment.
- a need for harmonizing state weed legislation was identified.
- a major conflict of interest remains unresolved: the planting and promotion of some pasture/fodder species which are also environmentally hazardous (some rangeland trees, shrubs and aquatic grasses)
- application of the "beneficiary pays" principle which operates within the production portfolios is not appropriate when "community good" issues are at stake; e.g. who funds large control programs on private land when lack of weed management affects the environment? Individual farmers often cannot afford adequate
- control measures but would benefit from control paid through the
- public purse. This is seen as contradicting the "beneficiary pays"
- principle and to date the issue is unresolved.
- government is still ambivalent in its support of the strategy as it recognizes the costs of weed management are high and ongoing, and the returns are politically low profile.

The recent awareness of weeds as a major conservation threat requires traditional areas of jurisdiction to shift or the problem "falls between the cracks."

The success of the strategy in conservation terms will depend heavily on the sustained level of Cabinet funding (which is related to public pressure) and on the institutional arrangements for its implementation. The institutional arrangements are a sensitive and important factor because principles and priorities could differ between the conservation and production portfolios. Traditionally weeds, as a problem of agriculture, were dealt with in the production portfolio. The recent awareness of weeds as a major conservation threat requires traditional areas of jurisdiction to shift or the problem "falls between the cracks". The shifting responsibilities are currently under negotiation.

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Community Outreach and Interagency Involvement: Examples from Maui, Hawaii

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Bold and comprehensive national and international strategies for dealing with invasions are needed, but often, it is activity at the local level that determines success. Loope tells the following story of a successful response to an invasion of rabbits in Haleakala National Park on Maui, Hawaii. Until 1990, Loope and his colleagues in the National Park Service were involved in little or no community outreach and had no contact with other agencies on Maui. In fact, they felt they had little in common with the state agencies; Forestry and Wildlife had introduced the axis deer to Maui in the 1960s and were quietly watching this known destroyer of rainforests reproduce and spread. There were other instances of neglect by state agencies, and their attitude seemed to be that biological control was the only acceptable method of dealing with invading species. But events in 1990 marked a turning point for the National Park staff in their relations with the public and the other agencies.

In July of 1990, six rabbits were reported at a camping area in the park. An initial investigation confirmed that rabbits occurred throughout an area covering 60 acres. Once established, rabbits would be even harder to get rid of than goats. Eradication of the rabbits was declared the #1 priority of the Park Service and a rush order was made for rabbit snares.

As they hurried to get an effective control program underway, they worried about how to control the rabbits without dispersing them or attracting adverse public reaction. After closing the campground temporarily and shooting the rabbits with silenced rifles, they quickly erected a fence, filed an abbreviated environmental assessment, and issued a press release. This was such a sensitive issue with the press and public that they put some energy into communicating with the press. The results were very successful as the story made the front page of the papers, the articles were consistently positive, and a ground swell of support came from the public.

This support led to the source of the rabbits, an individual who released six rabbits when he got tired of them and innocently decided to set them free. About 1500 snares were put out and 100 rabbits were caught. In May 1991, ten months later, the last rabbit in the park was caught. Public reports of sitings were key to the rapid success. People reported free roaming rabbits outside the park too. Rabbit establishment on the Hawaiian islands is a time bomb waiting to go off, but so far it hasn't happened. Rabbits have not established at low elevations because dogs keep them under control. But away from human habitation, where there are no dogs, rabbits could still become a problem in the future. There is also a problem with people releasing cats, but the rabbit story helped educate the public on Maui about the dangers of releasing exotic animals. Based on the rate of reproduction, if nothing was done, after five years there would have been about 14 million rabbits.

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A *Miconia calvescens* invasion surfaced as soon as the rabbit problem calmed down. Miconia is a neotropical tree that has taken over the island of Tahiti and has an incipient invasion in virtually identical habitat on Maui. They first noticed a tree on the roadside near a botanical garden about five miles outside the National Park. They soon learned of six populations and thousands of individuals, some up to 35 feet high. State agencies jumped in to help. They used a "wanted" poster prepared through interagency cooperation and publicized the problem through newspaper articles to inform the public and give credibility to the effort.

All of these methods were successful and by late 1992, Miconia was finally placed on the state's noxious weed list. Landowners as well as volunteers cooperated in the eradication effort and 20,000 plants (mostly seedlings) were removed over a couple of years. Concern had been stirred up and in August of 1991, a local group formed to lobby to ban this family of plants from the Hawaiian islands and carry out control work. All the agencies got together on this and the Hawaiian legislature appropriated funds for the control effort. In January and February of 1994, helicopter spraying was used to keep trees from fruiting. A committee got agencies to do their job of monitoring and control.

The source of the rabbits was an individual who released six rabbits when he got tired of them and innocently decided to set them free. Based on the rate of reproduction, if nothing was done, after five years there would have been about 14 million rabbits.

The Park Service is now involved in cooperative efforts against two official noxious weeds: fountain grass and ivy-fruited gourd, and are also involved in three other potentially highly invasive species: pampas grass, mullein, and German ivy.

Formal efforts now underway are led by the Natural Resources Defense Council and the Nature Conservancy to identify gaps in the legal/quarantine/control system and close them. These efforts began in 1991 and are expected to culminate this year with the completion of a statewide Alien Species Action Plan with 30-40 organizations involved. A key provision will be a highly publicized annual report to monitor progress. The main barrier to the success of programs that rely on interagency cooperation and community involvement is lack of financial resources; the commitment is there as well as the knowledge of what needs to be done.

Three principles emerge from these stories:

- Any program, especially one involving detection and elimination of alien species, will not succeed without committed individuals at the grassroots level, and interagency and interpersonal coordination, cooperation and bonding.
- If an agency creates a healthy climate for employees by clearly defining objectives rather than dictating specifics, and by giving reasonable support to a program's best efforts, even those that are somewhat unorthodox, good things can happen.
- 3 Public education is important and is possible. The press can be extremely helpful in getting the message out, especially with reporters with a track record of getting the story right.

Discussion

Dr. Loope thinks interagency task forces can be important, especially because agencies can sometimes have conflicting agendas. Local support is very helpful in eradication efforts. People for Ethical Treatment of Animals (PETA) raises money by attacking The Nature Conservancy's programs to eradicate invading species, and bad publicity can be very destructive for such programs.

Miconia, marmosets, and other harmful invaders are not yet on the noxious lists, so "black lists" are not working completely. The "dirty list" idea is fine but we have to get all the dangerous species on the list in a timely way. We could lower the presumption to put things on the dirty list, or raise the presumption to get things on a clean list, but they're not equivalent, according to Mark Miller. Dirty lists work but they have to be more comprehensive than they are. Clean lists have been problematic when tried.

A problem with all the current tree planting efforts is that many groups are planting invader species. Australia had proposed that potential importers must go through the routine process of testing and pay for it.

Loope says that the purpose/mandate of the National Park Service is to look at community effects of removing feral animals such as goats and pigs, to look at the biology and status of rare and endangered plant species, and to look at individual pest species and the technologies and strategies for controlling them.

Public education is important and is possible.

Risks of Biological Control of Invasions

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Understanding, prediction, and management of host specificity is the key to the safety issue, but it is not the whole story.

Before introducing a biological control (biocontrol) organism, the benefits and costs should be weighed in both economic and environmental terms.

Problems with Benefit/Cost Analysis:

- Even when the benefits are greater than costs, the magnitude of the costs may be so high as to make the action unacceptable or unfeasible.
- Benefits and costs that are unevenly distributed socially, geographically and generationally can present fairness questions. A process for resolving conflicting interests is needed.
- Excessive uncertainty or questionable valuation techniques may undercut the analysis.

Key attributes of biocontrol agents are their capacity to:

- harm other organisms
- survive
- reproduce
- disperse
- evolve

These attributes can be good or bad depending in part on host specificity. Understanding, prediction, and management of host specificity is the key to the safety issue, but it is not the whole story. A control organism may harm a non-target organism in a multitude of ways - from a direct trophic interaction that arises when the control organism consumes a non-target organism, to direct interference competition, to indirect interactions that can arise when the control organism and the non-target organism interact via intermediate species such as a shared natural enemy or a shared host.

The International Union for the Conservation of Nature (IUCN) position on translocation of living organisms:

- Release of a non-indigenous species (NIS) should be considered only if clear and well-defined benefits to human or natural communities can be foreseen.
- Release of a NIS should be considered only if no indigenous species is suitable for the desired purpose.

- No NIS should be deliberately released into any natural area; releases into semi-natural areas should not occur absent exceptional reasons.
- Planned releases, including those of biological control, entail three critical phases: rigorous assessment of desirability; controlled experimental release; and extensive release accompanied by careful monitoring and pre-arrangement for control or eradication measures, if necessary.
- Special consideration should be given to eradicating existing introductions in ecologically vulnerable areas.

Host specificity testing in biological control:

- predators and pathogens to control weeds
- predators, parasites, and pathogens to control pest arthropods
- microbial biopesticides (using bacteria, fungi, viruses, etc. to control pest arthropods and weeds)
- other types of biological control (fish for control of aquatic weeds, viruses for control of vertebrate pests, and newly evolving technologies based in biotechnology)

Review of safety record of biocontrol agents

Some exotic biocontrol agents were introduced to do a particular job and have ended up doing something different. For example, there has been a problem with agents feeding on non-target species:

- Chrysolina beetles eating ground cover in northern California
- Rhinocyllus weevils eating native thistles
- Tyria caterpillars eating ornamental plants and native wild flowers
- Cactoblastis caterpillars eating native cacti in Florida

A tingid bug was widely introduced to control a specific weed; it attacked a variety of a crop, sesame. However, a disaster was averted as on-target effects were localized along scales of space, time, and biological organization.

How confident can we be regarding the safety of biocontrol agents?

- Little monitoring except in agroecosystems
- Native communities have been neglected
- Expect time-lags in appearance of problems (it can take 5-10 years to see affects on target species and even longer for effects on non-target species)

Key questions regarding host specificity

- Test plants: How do we pick the non-targets for host- specificity tests?
- a) dominated by economically useful plants
- b) includes a small fraction of potential wild hosts
- c) inadequate predictive framework
- (Decisions about introductions should be removed from local political decision-making because there are national implications.)

Some exotic biocontrol agents were introduced to do a particular job and have ended up doing something different. For example, there has been a problem with agents feeding on non-target species.

Test insects : How do we deal with agent variety?

a) Specificity is expressed at individual, population, and species levels. b) Host range may change over time given the right combination of genetic variation, selection, and ecological opportunity.

A Case History

Early Tests

Prior to the introduction of the cinnabar moth into New Zealand from England in 1935, crops and ornamentals were tested to make sure they were not suitable hosts.

More Modern Tests

Instead of testing each plant, an attempt was made to develop a predictive framework. Prior to the release of cinnabar moth in Canada in 1961, several genera of the tribe Senecioneae and representatives of most other tribes of Compositae that occur in Canada were tested. Feeding and development were evaluated; did feeding occur on the host, and did the insect complete development? It was found that restriction for feeding occurs at the sub-family level and that restriction for development occurs at the genus level. This established a new philosophy for host testing.

Instead of tesing each plant, an attempt was made to develop a predictive framework.

What is the actual protocol?

It is conventional to assume vulnerability equals suitability for larval development in no-choice feeding test?

- but actual host range (field) is much smaller than potential host range (lab)
- need to distinguish probability and consequences of host use

Need to expand screening studies (Harris and McEvoy, 1994)

1. phylogenetic constraints
2. climatic constraints
3. physical and biotic habitat restrictions
4. oviposition requirements
5. plant acceptability for feeding
6. suitability for development

This process identifies gaps in knowledge and thus may expand basic research that would be useful to the whole field.

A more productive approach to risk would be to:

1. assess probability of attack; take into account sequence of factors
2. look at consequences of attacks on the non-target host

A measure of risk:

1. Probability of host utilization: habitat finding, host finding, host recognition, host acceptance, host suitability
2. Amount of potential loss for each level of utilization, taking into account mitigating factors
3. Expectation of loss

Host mechanisms that potentially soften the impact of natural enemies include plant dispersal, perenniality, iteroparity, and dormancy.

The storage effect hypothesis suggested that strong recruitment under favorable periods is stored in the adult population or the soil seed bank and is capable of contributing to reproduction when favorable conditions return. It requires that:

* environmental conditions vary, resulting in fluctuating recruitment rates;
* individuals survive over periods of poor recruitment as adults or buried seed.

There is a need for more evolutionary studies of host shifts:

1- micro-evolutionary requirements for host shift: genetic variability; strong selection; ecological opportunity

2- macro-evolutionary considerations in host shift: distinguish evolution by mutual descent from evolution by colonization

Safety factors in patterns of genetic variation and correlation:

preference x suitability = host utilization

no correlation - independence

positive correlations - host shift may be easier

negative correlations - host shift may be more difficult

Conclusions

Future work should emphasize:

- Statistical rigor in tests
- Validation of general approach
- Post-release monitoring
- Selected evolutionary studies
- Attention to both trophic and non-trophic effects
- Risk analysis weighing costs and benefits in environmental and economic terms (including probability of harm, consequences of harm, etc.)

Many introductions were made under a relaxed protocol. We can't recall them but we can learn from them. Therefore, we need systematic analyses and detailed studies of these past releases.

Discussion

Preventing harmful introductions is the highest priority. We need as good a protocol to protect against exotic invasions as we have to protect against mistakes in biocontrol releases. On the other hand, biocontrol practitioners see themselves as "do-gooders" and exempt themselves from rules. Nearly 1,000 biocontrol agents per year are released. How should we view introducing 60 control organism species to control one target pest species like the Russian wheat aphid? In the past, one agent (a ladybird beetle) was released without an identified target; it simply attacks soft-bodied insects. To cite another area of ignorance, the environmental impacts of agents like microbial pesticides are very poorly known.

We need as good a protocol to protect against exotic invasions as we have to protect against mistakes in biocontrol releases.

There is concern over biocontrol bacteria Bacillus thuringiensis (B.t.) used to eradicate the gypsy moth. It is a broad-spectrum larvacide that killed native lepidoptera. This could have been more harmful environmentally than chemical pesticides. We need to weigh the costs and benefits of losing the lepidoptera in a particular area versus a complete invasion by the gypsy moth.

There are serious questions about using exotics to control "undesirable" native species. The zeal to find such new organisms is frightening. There is a reluctance to attack native plants pests in this way, but not in controlling native insects that are perceived to be pests. One has to guard against philosophical errors on all sides of this issue. We need to look past individual species population impacts to community impacts. We should ask these questions prior to introduction of biocontrol agents, not after.

The current cost/benefit analysis is not very sophisticated; we still hear a lot about potential benefits without any discussion of potential risks and costs, i.e., "this agent could save $60 million for the rangeland" with no consideration of how much the natural system will pay for it.

Biological control of weeds

One agent was released without an identified target; it simply attacks soft-bodied insects.

Dr. McEvoy discussed 26 weed species currently managed with biological control, most of Eurasian origin, and 58 natural enemy species including 32 species of Coleoptera (beetles), as well as Diptera, Lepidoptera, mites, fungi, nematodes, and fish. In South Africa, 36 weed species are controlled by 60 natural enemies, also mainly beetles.

Biological Control of Weeds - a World Catalogue is a good resource; what works in one area has a good chance of working in another. Worldwide databases of biocontrol agents also exist and include information on characteristics of species controlled biologically.

Practitioners of biocontrol were surveyed about what factors they believe are limiting enemy effectiveness. Their responses tallied as follows:

Climate 44%
Predators 22%
Parasitoids 11%
Disease 8%
Incompatibility 33%
Competition 12%

Their recommendations emphasize a need to find better matches between organism and climate and between organism and host, but we also need better understanding of organism interactions within and between different trophic levels.

Basic Questions

What are the patterns in the dynamics of biological control systems?
How are they regulated?
How do they respond to perturbation?

1. show whether current enemies are adequate or whether new enemies are needed
2. create more reliable basis for extrapolation to new areas
3. elaborating and testing principles and predictions about host specificity and predictability

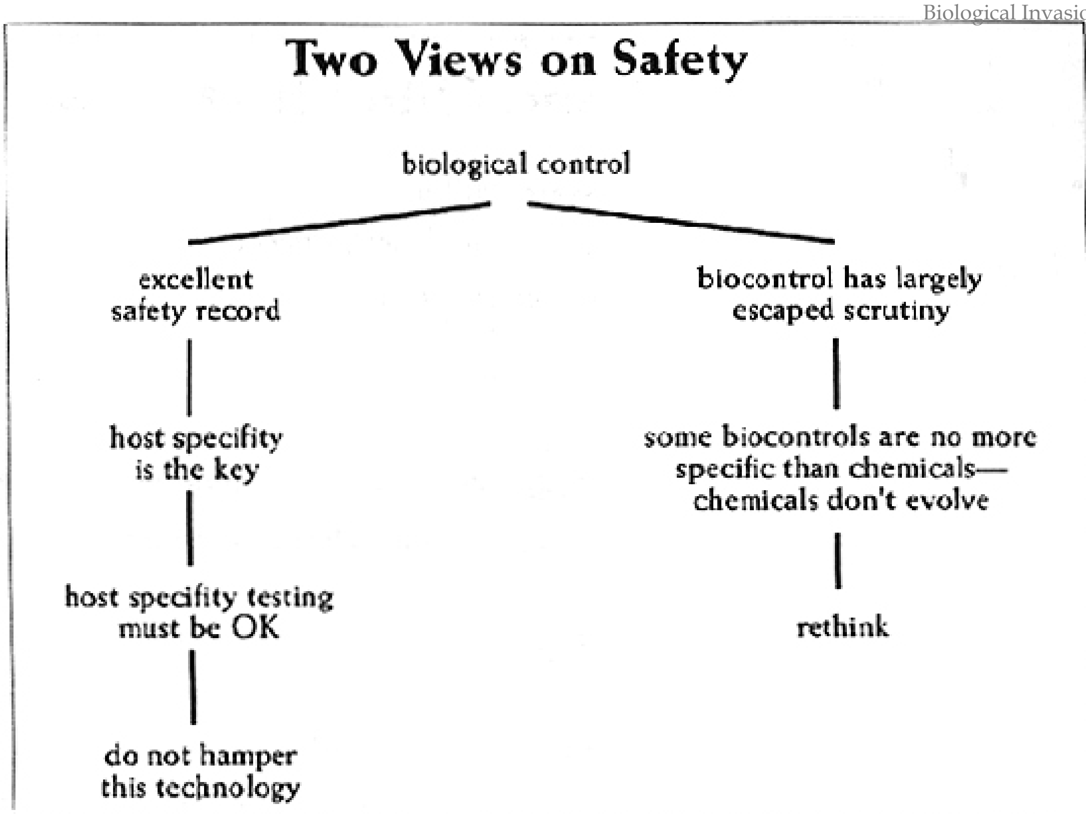

Figure 16.1: Two Views on Safety of Biocontrol Agents

ORIGINAL INTERACTION	EVOLVED HOST SWITCH	REFERENCE
biocontrol insect controls weed	evolves new host race that attacks beneficial plant	Ehter 1991 Andres 1985
phytophagous mite on lima beans	lab selection, switch to cucumber	Gould 1979
introduced caterpillar eats introduced parsnip	switches to native parsnip	Berenbaum and Zangerl 1991
legume-feeding Colias butterfly	shifts from native larval host plants to legume forage crops	Tabashnik 1983
native butterfly Euphydryas editha feeding on scroph Collinsia	switches to introduced weed Plantago lanceolata	Singer et al 1994
fruit flies parasitic on native hawthorn	evolved new host races on domestic apples	Feder et al. 1988, 1990; Bush 1989
native soapberry bugs eat native plant species	evolved new host races on three introduced plants	Carroll and Boyd 1992
gall fly on native Solidago altissima	evolved new host race on another native Solidago gigantea	How, Abrahamson, Craig 1993

Figure 16.2

Regulation of Biological Control Agents and Other Invasions

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Biological controls are invasions. They are developed and intended to have the characteristics of the worst pests.

Biological control involves intentional decisions about invasions.

Thesis

Because biological control concerns intentional introductions, usually by experts, if we cannot agree on sensible policies for biocontrols, it is unlikely we can develop sensible policy for less formal intentional introductions or accidental invasions.

Biological controls are invasions.

They are developed and intended to have the characteristics of the worst pests (and host shifts can happen). The weed control community is way out in front on asking good questions. The zeal of using alien agents to control native pests is frightening.

There is a lack of recognition that biocontrols are invasions

- There is a complete absence of legal literature on biological controls.
- Biological literature largely fails to recognize that biocontrols, like unwanted invaders, violate ecosystem integrity.
- Popular and technical press characterize biocontrol in only positive terms.

Questions for Deciding Whether Regulation is Necessary

- Does the activity have substantial potential costs?
- Are those costs adequately considered by market forces?
- If not, are those costs adequately considered by current law, regulations, or professional practice?
- If not, can current laws and practices be amended, or is a new law necessary?

Current Law: Three Approaches

- Quarantine and inspection acts: plant pest act, noxious weed act
- Barrier and Exclusion Acts: Lacey Act (black list of injurious wildlife)
- Protective Acts: Endangered Species Act

Problems with current law

- Focus on borders
- After the fact of identifying noxious species and endangered species
- Not oriented to central concerns like development of knowledge or responsiveness to invasions

Four reasons biocontrol researchers should favor new law

- protection of sound biocontrol research and programs
- limitation of tort liability
- Echium 8-year delay in Australia, 2 current possible lawsuits in US
- focus for additional funding
- opportunity of biocontrol researchers to contribute to emerging models of environmental management (choices are conscious and specific)

Policy ahead of its time? President Carter's Executive Order 11987

- came early in President Carter's first year
- only federal provision with spirit of AGCI invasions session
- over 15 years ago
- quickly isolated, and soon forgotten
- its origins and some possible reasons for its limited impact were discussed
- are we ready for 11987 today?

What went wrong with that Executive Order? The notion of harmful invasions was not as well established as it is now, there was a lack of enthusiasm for enforcement by agencies and the White House, and it got lost in a long list of priorities.

What went wrong with that Executive Order? The notion of harmful invasions was not as well established as it is now, there was a lack of enthusiasm for enforcement by agencies and the White House, and it got lost in a long list of priorities.

Policy Goals for Biocontrol and Invasions Laws

- collect information for research, decision
- making, general policy, and education
- decide what is acceptable and what is not-what is "natural enough"
- reduce harmful introductions
- support biological diversity (in its multiple forms)
- respond to harmful introductions quickly
- develop rational control programs

Policy Options

- process acts: like Australia's peer review process
- information and data sources: (Coulson, 1992) for whom and for what purpose?
- substantive preferences
- funding and policies for (a) stages of invasions and (b) types of areas
- education

Substantive Preferences

- black, white, gray, and rainbow lists: its possible to have a rainbow policy; white list as champion of commerce; preferences and presumptions; the "need to know more" category
- oppose use of alien organisms on native pests
- requirement of assessment of harmfulness of pest and alternative strategies

Model Acts

- wide use of model acts in other areas
- current benefits: coherent statement of problem and goal; rally support
- mid-term benefits: points of citation; gradual development of sound policy and support; use by states or other countries
- long-term benefits: ready when needed (when another zebra- mussel type problem arises)

There is no requirement of an Environmental Impact Statement (EIS) for introducing an organism; it's at the discretion of the agency involved.

Dangers of Excessive Discretion: the Virtues of Law

- the fondness for discretion by experts and agencies and recognition in law of judgment and special cases
- lessons of the listing acts
- a Man For All Seasons: the law is an imperfect shield-but it can be a shield; the law is an imperfect sword-but it can be a sword.

Other virtues of new laws and vices of old ones

- assumption (fallacy) of impact: entrenchment; laws as social tools, subject to social context; the same words at different times will have different effects
- the effects of novelty and decay
- ground up reform as a tool for evaluating current law
- ground up reform and incremental reform are not inconsistent

Three model laws in related areas

fish and wildlife; honey bees; and vegetation in natural areas

There is no requirement of an Environmental Impact Statement (EIS) for introducing an organism; it's at the discretion of the agency involved. When there is a proposal to eradicate an organism, on the other hand, it can require an Environmental Assessment (EA) or an EIS.

The Carter Executive Order doesn't apply to species movement within the US outside of their native range-only to species from outside the US coming in or natives going out. Executive orders are directives, not laws; and they don't expire.

How to deal with invasive species is a policy decision worthy of public notice and comment; it shouldn't happen in the basement of some agency.

Besides writing new legislation, another possibility is to get the Clinton Administration to implement the Carter Executive Order. Most people involved in this industry do not want regulation. How do we get the nursery and pet industries to see regulation as in their interest? One answer: as states set conflicting regulations, it might be in their interest to support federal legislation. We must build relationships with these industries, and bring them in early in the

process. Liability issues are key for these industries (sales of plants on the noxious weed lists and potential liability for selling them). Predictability is important for them too; volatility makes them nervous. The political process will take years. What is the next step?

A draft five year plan

Statement of principle; model act; local database and experts; local media.

This is *not* a subtle concept. It should *not* be difficult to implement in policy. When the invader is clear (like kudzu, etc.), people are aware and they respond. When you're looking at changes in complex ecosystems, it's more difficult.

The above presentation by Marc Miller set the stage for the group's effort to draft a model law concerning harmful non-indigenous species. A copy of this draft law, currently under continuing development, is an appendix to the report for AGCI's Session III.

The Carter Executive Order doesn't apply to species movement within the US outside of their native range- only to species from outside the US coming in or natives going out.

Policy strategies in pursuit of ecosystem integrity:

- policies aimed directly at integrity (i.e., purchase, protection to change status of land)
- policies aimed at factors which threaten or support integrity

What makes a wise law?

clarity well articulated goals
coherence focused policy goals
simplicity hard to avoid or define away
efficiency avoidance of bureaucracy
efficacy testable goals importance of private action: skepticism about government and minimization of political shifts

Puzzles in developing such policies

- It's hard to define ecosystems
- It's hard to prioritize ecosystems: hard to choose
- It's hard to measure losses and gains

There is also difficulty in identifying coherent spacial units for policy

- areas of biological and cultural significance
- biological measures versus cutting up the country into grids

Concept of baselines as a policy tool; not just change, but points in change.
Possibilities

- system in absence of humans
- at fixed points in human development
- what is natural enough?

- what would a native park look like?
- restoration ecology?
- how to explain to non-biologists?
- baseline for integrity?

A proposed Florida approach privatizes the issue of control of invasive species, making it a misdemeanor to let kudzu spread from your land to another's land; is this do-able? Is it the best way to restrict the spread of kudzu? The notion is good, but this particular law may not be the best way. Who is responsible? Private land owners are responsible for controlling weeds on their own land.

Socio-Economic Aspects of Biological Invasion, A Case Study: the Golden Apple Snail

Rosamond Naylor
Stanford University, Institute for International Studies
Stanford, California

Of all species introductions in agriculture, 35% come from southwest Asia, 15% from southeast Asia, and 21% form South America. Crops are moved all over the world. Less than 1% of the world's cereals, starches, fruits and vegetables originated in North America, though it is now considered to be the breadbasket of the world.

Regarding intentional introductions, how can sensible risk analysis be performed to help avoid harmful invasions? A case study of a problem invasion is the golden apple snail in Asian rice systems.

The golden apple snail (*Pomacea canaliculata*) invasion provides important lessons for economists as more intentional and unintentional introductions can be anticipated under the Global Agreement on Tariffs and Trade (GATT) and the North American Free Trade Agreement (NAFTA). The golden apple snail was intentionally introduced from Argentina to Taiwan in 1981 as a potential food source and was subsequently introduced into other Asian countries. Pomacea snails were confirmed to have infested 34 of the 47 rice-growing districts in Japan by 1986, and in the Philippines, the proportion of wet-rice area infested by the golden apple snail rose from less than 3% in 1982 to as much as 15% by 1991. In China, Vietnam, Thailand, Malaysia, Indonesia, Taiwan, South Korea, Laos, and Papau New Guinea, the snail has already invaded several of the main rice growing areas.

The stakes of the golden apple snail invasion are very high because rice is the major food and employment source in Asia and yields are already plateauing. Another major problem that reduces yields could be devastating. Could we have predicted this kind of invasion and its impacts? It wasn't known that the snail would feed voraciously on young rice seedlings and would be dispersed through the extensive irrigation networks of rice-growing regions. The snail is now the #1 pest in the Philippines. This case points to the need to analyze and predict probability of invasion and probability of damage from invasion versus benefits involved in the medium term - 5 to 9 years in the future.

It wasn't known that the snail would feed voraciously on young rice seedlings and would be dispersed through the extensive irrigation networks of rice-growing regions.

Naylor went through Sara Reichard's list of what makes a successful invader and applied those criteria to the snail. The characteristics that make the snail a successful invader are the same ones the entrepreneur looks for to maximize profits from introducing the snail as a potential food source (rapid reproduction, etc.). But the potential effects of the snail on the major food crop - rice - were not examined in advance. We now know that the damage has been enormous while the benefits have been very limited. There was no market testing prior to the introduction and once cultivation began, it was discovered that there was no market. European health restrictions limited the European export market, and the local Asian populations simply didn't like them.

The costs of the golden apple snail invasion in rice production includes the direct costs of controlling the snail, the costs of replanting (after initial destruction of seedlings by snails), and rice yield loss. The huge costs of replanting greatly reduces farmers profits. (See Tables 18.1 and 18.2 for details on financial costs.) Direct seeded rice is the most vulnerable to snail damage. Many new rice varieties are direct seeded, including the new "super rice" varieties that are expected to raise rice yields by 40% or more during the next decade, so the snail could become an even bigger problem.

In addition to the affects on rice yields, the golden apple snail has a direct impact on human health. The snail is an intermediate host of the lungworm,*Angiostrongylus cantonensis*, which is normally parasitic in rats, but which also causes the fatal disease eosinophilic meningoencephalitis in humans. Moreover, the snail acts as an intermediate host to various trematodes that cause skin irritations in humans.

The potential effects of the snail on the major food crop-rice- were not examined in advance. We now know that the damage has been enormous while the benefits have been very limited.

The molluscicides and insecticides used for snail control are persistent organotins that are toxic to people and other species. Human health effects include nails falling out, skin problems, blurring vision, and blindness. There are also significant and long- lasting downstream effects on natural marine ecosystems. The types of chemicals generally used are persistent and accumulate in sediments. In addition, these chemical controls are not effective without good water control, and irrigation is not always well- controlled, especially in the monsoon season. Many of these chemicals have now been banned in Japan, Taiwan and the Philippines. There are currently no known chemicals which are safe, effective, and cheap enough for farmers to use.

Integrated snail management is being advocated, including hand picking of snails, herding ducks to eat smaller snails, better water control, spot pesticide treatment, and more seeding. However, results of the integrated approach do not reveal how effective each component is. Hand-picking is the most effective but also the most labor intensive. Ducks are effective but only during one part of the life cycle of the snail. And improving water control has proven very difficult.

Biological controls being considered or tried include raising common carp and Nile tilapia to eat snails, genetically manipulating snails to breed less rapidly, and botanical pesticides. Because botanical pesticides are biodegradable, it is believed that they are less likely than synthetic pesticides to leave harmful residues; however, they may also be toxic and cause resistance to build up in the pests over time. Another strategy is to try to get people to eat the snails by sending out brochures with snail recipes.

The extensive economic, ecological, and health ramifications of the golden apple snail invasion in Asia provide a perfect illustration of what Elton (1958) meant by "the piling up of new human difficulties." This invasion is clearly a case of an introduction that should not, and perhaps would not, have occurred if closer policy attention had been directed toward the full set of risks associated with it. It also raises the question of quarantine procedures, which are not very stringent in many industrialized countries, and noticeably absent in many developing countries where there is a lack of both training and regulation on species introductions.

Institutionalizing quarantine programs in developing countries that can effectively mitigate the introduction of exotic species is critical for two reasons: to reduce the scale of biodiversity loss and ecosystem damage globally, and to avoid large economic losses that poor countries and poor

people can ill afford. Given that exotic species are vulnerable at the early stage of establishment, investments in programs to avert introductions or to eliminate early establishments have a much higher return than investments in control of well-established pests. For example, the resources spent by Philippine rice farmers on snail damage could have been better spent on implementing a viable quarantine program for all agricultural introductions.

Biological invasions in agriculture, as well as in largely natural systems, serve as yet another warning that ecological disruption, often severe and permanent, can be caused by human action that is driven by the desire for short-term economic gains. Bringing ecology into agricultural policy analysis thus deserves to become a high priority. Greater attention to ecological principles is needed, in particular, in assessing the risks of species invasions, in designing integrated pest management strategies, and in defining quarantine procedures. In additional, understanding economic factors that influence human behavior is critical in defining the ecological equilibrium of an agricultural system.

The invasion is clearly a case of an introduction that should not, and perhaps would not, have occurred if closer policy attention had been directed toward the full set of risks associated with it.

Table 1: Economic Costs of Snail Damages in Phillipine Rice Systems*

1990 U. S. dollars in millions

Description of Costs		Cost Amount
Yield loss with snail control and replanting		
	high	17.8
	low	12.5
Replanting costs with snail control		
	high	10.3
	low	2.8
Costs of control of molluscicides and handpicking		
	high	17.2
	low	12.5
Total costs of snails to farmers		
	high	45.3
	low	27.8
Yield loss with no snail control or replanting		
		48.0

* Sources and Assumptions (1990)

Source: FAO (1992b)

- Paddy production: 9.88 million tons
- Rice area: 3,433 million ha
- Yields (with snail) 2.9 ton/ha (without snail 3.0 ton/ha)

Source: IRRI World Rice Statistics, updated from IRRI (1991b) by personal communication with IRRI Economics Program (1995)

- Farm harvest paddy rice (in pesos): 4260/ton
- Agricultural wage: $1.74/day

Source: IMF (1991)

- Exchange rate: 24 pesos/US$

Source: Ketelaar (1993), Revilla, Estoy, and Salazar (1991), Rice IPM Network (1991)

- Infested rice area: 11-15% total rice area

Source: Warburton and Pingali (1993a, b)

- Replanting costs: 758 persos/ha (low estimate), 2738 pesos/ha (high estimate. 2 crop/yr
- Total molluscicide and insecticide use for snails: 40,000 liter fentin acetate, 20,000 liter fentin hydroxide, 110,000 liter fentin chloride, 400,00 liter endosulfan
- Pesticide prices: fentin acetate 700 peso/liter, fentin hydroxide 623 peso/liter, fentin chloride525 peso/liter, endosulfan 223 peso/liter
- Handpicking (when pesticides are used): 6-12 day/ha (2 crops)

Table 2: Cumulative (present value) costs of the snail invasion in the Phillipines

1990 prices / millions of dollars

	1980-1989[1]	1990[2]	1991 forward[3]	Total Costs *present value*
5% discount rate				
high damage	243	45	893	1181
moderate damage	152	28	584	736
10% discount rate				
high damage	294	45	447	786
moderate damage	183	28	306	489
15% discount rate				
high damage	355	45	300	700
moderate damage	221	28	204	425

[1] Assumes linear growth in infested rice area and constant snail density of 1 snail per square meter.
[2] 1990 costs follow directly from Table 1.
[3] Assumes that real prices and the amount of yield loss, replanting, and control measures remains constant.

Invasive Weeds

John Randall
The Nature Conservancy, National Exotic Species Program
Galt, California

In general, the Nature Conservancy is nervous about releasing biocontrol agents because they can be more permanent in the environment than chemicals.

The Nature Conservancy owns and operates 1300-1500 preserves of various sizes. Their mission is to preserve and protect species of life, and the land, air and water they need to survive. They carry out this mission by buying or legally protecting land. John Randall's job is to look at the most impacted parts of the preserves and focus on weed control questions: what to attack first, how to do it, and if it should be done at all.

A variety of weed invasion problems exist on their preserves, including leafy spurge on the east face of the Rocky Mountains in Montana. They are unable to control it with any herbicides, even the worst, most water soluble, persistent chemicals that could leach easily to groundwater.

In general, the Nature Conservancy is nervous about releasing biocontrol agents because they can be more permanent in the environment than chemicals.

One question that has arisen in this work is, do weeds do so well because we brought their "friends" (as well as because we left behind their "enemies")?

The California Exotic Pest Plant Council is an advocacy group that promotes solutions to these problems.

John Randall thinks it would help to produce lists for the public and the news agencies of what the problem plants are.

What Makes a Species a Successful Invader?

Sarah Reichard
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Dr. Reichard's research involves a study of woody invasive plants in North America. She has identified 236 species in 125 genera and 53 families that are successful invaders living in North America. Successful invaders are defined as species introduced far outside their native ranges which are able to establish themselves and reproduce outside of cultivation, as if they were native. Unsuccessful invaders are defined as species introduced to North America prior to 1930, that have never been documented as existing outside of cultivation; Reichard has identified 114 species, 80 genera, and 48 families of unsuccessful invaders.

Successful invaders are defined as species introduced far otuside their native ranges which are able to establish themselves and reproduce outside of cultivation, as if they were native.

Reichard began by identifying a list of characteristics that "conventional wisdom" says make species successful invaders. Preliminary observations and anecdotal evidence are the sources for this list. Not all of these generalizations have been proven; indeed, some may well turn out to be false. This list is not based on large scale surveys or statistical analysis, so we shouldn't accept this as "truth." With that caveat:

Successful invaders, in general:

- have widespread distributions and are abundant in their native range (habitat generalists; possibly higher genetic variation; higher probability of being introduced, especially accidentally)
- have high genetic variability (high heterozygousity provides more adaptability to varying conditions)
- have a close correspondence of climatic regions and habitat between their native and invaded ranges (having evolved under certain conditions, they won't thrive under radically different conditions)
- are feeding generalists (animals) or tolerant of varied soil conditions (plants) (more adaptable to unpredictable conditions in the invaded range; there is very little support for this generalization, little predictive ability)
- are successful because they are released from the predators in their native range (removal from predators allows more individuals to reach reproductive stage; Reichard says there is very little support for this in the plant world)
- are associated with humans for dispersal and/or resource enhancement (all of the 236 species Reichard found to be successful invaders were introduced by humans; in addition, humans degrade site conditions, facilitating invasions)
- have highly effective dispersal mechanisms, in addition to humans (for invader to expand, it must be able to disperse and build populations away from the mother

population; successful woody plant invaders are 60% biotically dispersed and 40% abiotically dispersed)

- have short juvenile periods (allowing them to reach reproductive age quickly, accelerating the population size; successful woody plant invaders mean juvenile period is 4.03 years, while that of unsuccessful invaders is 6.9 years)
- are self-compatible or able to colonize from a single fertilized female (effective dispersal may place individuals far from others and reproduction must continue for invasion to succeed; successful woody plant invaders are 44% self-compatible compared to 25% self- compatibility among unsuccessful invaders)
- have high reproductive output and are therefore able to build populations quickly (invasions progress faster and lead to greater success if populations increase quickly; examples include high output of zebra mussels, fire ants)

The “missing predator” characteristic is the one most often sitedin the popular press (because it is easy to understand), but it is not, in Reichard’s opinion, the most significant factor in a successful invasion

We should stop thinking of these things as truths; they are really hypotheses and require more research to test them. We also need to link research to action and use this type of information to perform triage Ñ to decide which invaders we can and should seek to control or eliminate. There is some discussion around questions such as: Should we use this approach to predict which species should be excluded? And once we make such a prediction, can we use a blanket approach to exclude whole classes of species, and place the burden of proof on those who wish to bring in species that fit a set of characteristics?

Note: The “missing predator” characteristic is the one most often sited in the popular press (because it is easy to understand), but it is not, in Reichard’s opinion, the most significant factor in a successful invasion. There is a suite of factors that make an invasion successful.

The information that follows is based on Dr. Reichard’s research and analysis, as opposed to the preceding material, which is anecdotal in nature.

Can we predict invasions of native plants?

Reichard conducted a discriminant analysis of 236 successful invaders and 114 non-invasive woody plant species introduced to North America in order to identify variables that distinguish the two groups. These variables are largely related to increased reproductive output and stress-tolerance, although the knowledge that a species invades elsewhere in the world is the best single indicator.

From this discriminant analysis, as well as characteristic comparisons, and classification and regression trees, a predictive flow chart was developed as a practical method of evaluating the risk of invasiveness (see Figure 1). The discriminant analysis model was created using 149 species (75%) selected at random, and validated on the remaining 58 species (25%). Based on this model, Dr. Reichard would have denied admission to the US to 86% of the invasive species and would have admitted 70.8% of non-invasive species. The predictive flow chart, tested on all of the successful and unsuccessful invaders, admitted no invasive species (although 11% were recommended for possible admission following further analysis) and admitted 38% of the non-invasive species (with another 39% recommended for possible admission following further analysis).

Tree Improvement as a Strategy for Coping with Invasions

Scott Schlarbaum
University of Tennessee, Department of Forestry, Wildlife & Fisheries
Knoxville, Tennessee

The Tennessee forest is predominantly upland forest dominated by Oak-Hickory (71%). About 80% of this forest is non-industrial, privately owned land while about 8% is privately owned by the forestry industry.

The tree improvement program of the University of Tennessee has traditionally served the needs of the timber and Christmas tree industry, and has now added a wildlife component. Many tree improvement programs at the land grant universities have died out. In dealing with plant pests, if you can't control them, you're back to plant breeding, so much more work is needed on this issue.

Regarding the American Chestnut blight in the 1930s that came through Tennessee and wiped out this species, Schlarbaum thinks it can be restored to some degree but money is needed and time is of the essence. Most of gene pool has already been lost and the rest is going quickly.

Regarding frazier fur and red spruce in Smoky Mountain National Park, balsam woolly adelgia moved into the area in 1958, feeding on frazier fur and killing it. It cannot be controlled on a large scale. A soapy spray can kill the adelgia on a specific tree but doesn't control the overall problem. With an aggressive breeding and testing program started in the 1950s, it would have been possible to have trees that were 75% frazier fur that were resistant to adelgia, but it wasn't done.

Butternut canker has killed most of the butternut trees in the Smoky Mountain National Park. Dogwood anthracnos disease is a big problem and funds are needed for breeding programs, seed collection, etc. Gypsy moths are hitting the oak population. Hemlock are threatened by woolly adelgia, and this problem is moving into North Carolina now.

Recent insect diversity studies reveal that over 20% were Asian oak weevil. These insects eat the roots of oak trees and are very destructive to seedlings. What can be done? There is quite a bit of monitoring going on, but more funding is needed for research into solutions.

The western white pine breeding program was successful and rust- resistant trees have now been introduced back into the system.

With an aggressive breeding and testing program started in the 1950s, it would have been possible to have trees that were 75% frazier fur that were resistant to adelgia, but it wasn't done.

Biological Invasion as a Global Change

Peter Vitousek
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Stanford, California

Biological invasions are one of a set of ongoing global changes caused directly by humans, i.e. CFCs causing ozone depletion, increases in CO2 and methane, harvesting of natural populations of predators, biological invasions, land use changes, etc. These then have further effects, causing secondary changes, i.e. climate change and biodiversity loss (from land use and land cover changes).

Wave after wave of invaders devastate natural ecosystems, yet the damage caused by invaders isn't seen as a serious threat.

Human activity is systematically breaking down the distinctiveness of ecosystems by accelerating the transport of organisms. People have accelerated the mobility of species, blurring the distinctiveness of biota. Winners and losers emerge from this process; some species will extend their range and populations while others will move toward extinction or be constrained. Charles Elton's 1958 book on species invasions is evidence that this is not a new concept.

Evidence for change in every aspect of how communities work is especially apparent on islands, though it is important everywhere. Examples include: California's Eurasian grasses/weeds that make the hills golden; fauna of aquatic systems in which native species are profoundly endangered as one set of invaders replaces another; the rebounding forests in Eastern North America (often cited as examples of the resilience of systems) are affected dramatically by exotic invasions. Wave after wave of invaders devastate natural ecosystems, yet the damage caused by invaders isn't seen as a serious threat. Why? No end to this process of blurring the biota of the Earth is in sight. How important are these changes?

The loss of biodiversity is perhaps the least reversible of all global changes, and it is dominantly caused by land use and land cover changes. The second least reversible global change is biological invasion, Vitousek says, and this breakdown of biogeographic barriers drives more extinction of species and reduction of diversity than any other factor except land use changes. And invasions interact with the other global changes.

Introduction of exotic grass species, particularly those that carry fires, are themselves an agent of land use change because they enable fires and lead to a large scale change from woody vegetation to grassland savanna. Even in the much longer term, beyond such direct reactions, human decisions to clear land can be predicated on the availability of exotic species to replace them.

Invasive animal species are also agents of disturbance that drive land use changes after their introduction. Why don't invasions get the attention they deserve, compared to, say, acid rain? Are they too familiar? Are there no disaster stories about them? Why is biological invasion treated as distinct from other components of global change when it could, in fact, be more important than many of the other factors?

Discussion

Most people don't know if species are native or exotic and are essentially unaware of the invasions problem. Chestnut, elm and fraser fur declines in eastern U.S. forests due to exotic pathogens was largely known about. But public perception of the magnitude of the problem is not great. Also, the issue of "blame" is a problem; there's no one to directly blame, as in issues like acid rain. Also, there are questions about what is natural and beautiful in an environment? Exotics such as calla lilies, blackberries, and pheasant, are seen as nice additions, not invaders. Is calling them invaders a form of racism? Biotic impoverishment of many parts of the Earth is largely due to invasions by exotics. It helps to stress the positive, i.e., protecting and supporting native species, rather than the negative, i.e., excluding exotic invaders.

Why is biological invasion treated as distinct from other components of global change when it could, in fact, be more important than many of the other factors?

APHIS and Strengthening the U.S. Response to Invasions

Randy Westbrooks
Animal and Plant Health Inspection Service (APHIS)
United States Department of Agriculture
Whiteville, North Carolina

Some 4,500 exotic species have been established in the US, and 650 of these are known to be harmful.

In 1974, a US law was passed that commanded that we keep out exotic weeds; Randy Westbrooks believes we should actually do it. While he believes that we can and should control exotics, he points out that our nation is "hooked" on them. For example, at dinner last night we had 14 exotic species and just two native ones.

The idea of harmful exotics is not new but attitudes on the subject have changed in the past 20 years. There used to be no such thing as a weed; not anymore. Some 99% of this country has been used up for the benefit of one species - Homo Sapiens. Humans have cut down 32 million acres of long leaf pine forest in North Carolina alone. It is essential to at least maintain the last 1% of this country that is left in parks.

Biological pollution is a global issue. For the US, the Animal and Plant Health Inspection Service (APHIS) is the keeper of the gate. They can do more and we can do things too. We can't stop all invasions but we can minimize them. Weed science, biology, and plant quarantine are three fields concerned with non-indigenous invasive species.

The issue of species movement began with Pangea, the huge supercontinent that existed 250 million year ago when species could move around freely. When the continents began to split up about 180 million years ago, complex, balanced, distinct ecosystems developed; this would have continued if people hadn't come along. Differing climates and soils, the physical separateness of the continents, and other factors maintained these distinct ecosystems. There are four times as many species on Earth as would be predicted given the land area. One reason for this is that the separate continents have acted as species pumps.

But when humans started migrating around the globe, in the last couple of thousand years, biological invasion really became a problem. Some 4,500 exotic species have been established in the US, and 650 of these are known to be harmful. They cause both ecological and economic harm, reducing biodiversity in ecosystems and adversely effect agriculture and other human activities. The modern era on Earth might be referred to as "The Homogocene" - the time in which the worlds flora and fauna are being homogenized by humans.

Non-indigenous invasive species are biological pollutants that pose a threat to pristine and disturbed ecosystems. Some examples are feral burrows, insects, the HIV virus, and fire ants. We are just trying to control fire ants now, because we know we cannot eliminate them. They came into the US with a load of lumber in 1905 and spread like wildfire throughout the Southern US.

Another invader is Kudzu, a plant introduced in 1876 by Japanese immigrants in Philadelphia. It was also introduced in the 1890s in Florida as cattle forage, and in the 1930s as a roadside erosion controller in Alabama. Kudzu is a pea-like legume that has become an enormous problem in many several US regions. Currently, Kudzu in the US does not produce many seeds because we don't have the pollinating insect that spreads it in Japan. If this insect ever does enter the US, we will really be in trouble. It wasn't until 1963, that we began to realize we had made a huge mistake by introducing Kudzu into the US.

Crab grass is an invasive plant brought into the US at the request of Polish immigrants in 1849. The Gypsy Moth was brought into Massachusetts in 1869 to spin silk and was released during a storm, resulting in widespread infestation. The Asian gypsy moth is now a problem invader in many states, including North Carolina.

The melalueca tree was brought to Florida from Australia to dry out swamp land and make it suitable for agriculture. It is very difficult to predict whether a species will become a harmful invader since we don't know how species will react to new conditions. The melalueca tree seemed relatively harmless for 50 years before its population began exploding in the Florida Everglades. In another Florida example, the state spends $12-14 million a year to keep hydrilla clear of boat ways. Often, people driven by profit motive cause these invasions.

Crop losses and control costs due to weeds are abot $1.5 billion a year in the US.

Environmental Effects of Biological Pollutants:

- Wholesale ecosystem changes
- Displacement or extinction of native species
- Reduction of biodiversity
- Genetic contamination

Crop losses and control costs due to weeds are about $15 billion a year in the US.

Though very concerned about the effects of chemical pollution and the bioaccumulation of pesticides and other chemicals in ecosystems, Westbrooks believes that biological invasions are an even more significant problem than chemicals in the environment because they are longer lasting.

USDA APHIS is the keeper of the national gate, with agents stationed at all ports of entry. But this is where the invaders come from. The long term goal for APHIS is to protect agricultural and natural ecosystems from invaders before they become biological pollutants.

About 75% of row crop weeds in the US come from other countries. So most of the chemicals we use and most of the money we spend on controlling pests and weeds are due to exotics. Westbrooks thinks it makes sense to use pesticides to control large infestations rather that trying to use biological controls which may not be successful and could allow invasions to spread.

Experience has taught that certain commodities from certain countries are likely to be contaminated with exotic pests. The 1974 Noxious Weed Act provides authority to control 75 species of weeds which come into the US on ships, planes, in water and dry ballast, and in agricultural commodities. APHIS tools for excluding noxious weeds include an inspection guide, an identification guide, and seed collection. However, there is a major problem with the listing system for noxious weeds Ð it takes too long to get dangerous invaders listed for exclusion.

Witchweed is a root parasite on corn and sorghum from Africa. It reduces corn yield 50-75% in ear size, and kills some plants. Tropical soda apple (native to Brazil), is a new exotic weed in Florida that is being spread to the US West in cattle that are moved to range land there. It is also spread by raccoon, deer, and infested sod.

If such invasions continue, the Earth will become simpler and poorer biologically Ð instead of six bioregions, there will be one. Biological pollution is the single most underestimated threat to sustainability. We generally wait until things get out of hand before we do anything about them. Prevention is always better and cheaper than a cure. Can we change our reactive stance to one that is more proactive?

Biological invasions are an even more significant problem than chemicals in the environment because they are longer lasting.

We need to use caution in the movement to free trade. The North American Free Trade Agreement (NAFTA) and the Global Agreement on Tariffs and Trade (GATT) have potentially frightening implications for the movement of species around the planet. If we become a true global village, the final chapter of biological invasion may come to pass. People who want to bring in nonnative species for profit should have to prove that the species has never been a problem as a weed or invader elsewhere. That is not enough though, because there are some species that don’t seem to a problem right away but then become a problem later. What can we do? We can work harder to determine the vectors of unintentional introductions, and exercise more control over intentional introductions.

We need research that leads to action - not either one in isolation. Some states have noxious weed laws and can list species independently of federal law, but some do not. The interstate control question is a real morass - very little has existed until very recently. Laws are very different from state to state and conflicting jurisdictions are problematic. APHIS also introduces species for biological control, which may seem like a conflict with what their main purpose is. Education of the public and school children is a critical component in making the APHIS system work.

Invasions on Public Lands

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This is a tale of two grass species introduced into two different ecosystems. Both are bromes, both are annuals; they are similar in many ways. Both proved to be successful invaders, but with vastly different effects.

Japanese brome was introduced into a Western wheatgrass- dominated system. Will a fire management plan to control Japanese brome work? Will Japanese brome plots burned in April decrease in density after the first year? That depends on the weather. The density of the seedlings is largely a function of precipitation in the fall and the amount of litter on the ground. In a dry year, litter amount is very important; in a wet year, it is less important.

Field experiments and a simulation model were used to determine whether fire control of Japanese brome would be possible. Results indicate that we can control but not eliminate Japanese brome with fire. Without fire western wheatgrass and Japanese brome made up 95% of the standing crop. There is more productivity in the system with the brome than without it. Other important elements of the system are not affected - it is a “successful” introduction - there is not much benefit but not much harm either. There is a reduction of some native species, but no major ecosystem effects.

In southern Idaho, Bromus tectorum or cheatgrass, has been introduced and now dominates the system. The prevailing management approach has been to seek more competitive species to plant. The biggest problem is that fires are more prevalent once the cheatgrass is established. Some 83% of fires occurred in cheatgrass dominated areas, and 90% of burned acreage occurred in cheatgrass dominated areas. It’s not that the cheatgrass out-competes the natives - it’s the alteration in the fire regime that’s detrimental to the native plants. So we’ve often taken the wrong approach to the problem. The region is critical winter rangeland for mule deer and other animals, but cheatgrass has little value in the winter.

It’s not that the cheatgrass out-competes the natives - it’s the alteration in the fire regime that’s detrimental to the native plants. So we’ve often taken the wrong approach to the problem.

Thirty ungrazed study sites in the Snake River plains were selected. In one 700 acre Kipuka; there had been no grazing and no fires for 110 to 120 years. There were lots of perennials and sprouting shrubs, and cheatgrass was there waiting for a break. After the area burned, the sagebrush was dead. The soil under the shrubs has 4% organic matter compared to 0.5% between shrubs, so new shrubs tend to sprout under old ones. There was no sagebrush left at all after a couple of fires in a few years. Fires were typically small; sagebrush seeds are very short-lived (less than a year to less than two years). If a second fire occurs before replacement, that’s the end of sagebrush there. One area has burned 16 times in 30 years. In that area, all the remaining species were introduced varieties and all were annuals.

Increasing fire frequency wipes out native, perennial species and encourages invading annuals. Cryptogams had almost 100% ground coverage without fires and perennial grasses dominated. These both drop off very fast with increasing fire frequency while exotic annuals increase proportionately. None of these areas were grazed, so vegetation could not be affected by grazing in these areas. Species richness declines based on fire probability in any given year. Small patchy fires were part of the system naturally, but what we have now, in cheatgrass-dominated areas, is a positive feedback loop, an accelerating spiral in which more cheatgrass yields more fires which yields more cheatgrass. The continuity of fine fuel in the cheatgrass dominated areas causes fire to move easily through these lands.

But in the first example of the Japanese brome, fire didn't effect the system much at all, in contrast to the experience with cheatgrass. Changes in nutrient cycling and water retention potential have profound implications. Shrubs trap snow; without shrubs, moisture flows out of the system. By killing native species and changing the fire regime, the invading species alters the hydrology and nutrient cycle of the system. Any useful functions of animals are lost because many animals don't come into cheatgrass environments.

Increasing fire frequency wipes out native, perennial species and encourages invading animals.

So the lesson of this example is that we need to address the fire regime, rather than focusing on competing with the invaders, since competition is not the primary problem. There is not enough money to re-seed all these areas and besides, the most important factor is to reduce fire frequency. Programs that plant strips of crested wheatgrass ("green strips") have proven valuable in reducing fire frequency. Cheatgrass does not readily establish in these strips and they tend to stop fires. Although the green strips produce more fuel, its poor distribution stops many fires.

Grazing is an important part of the system and must be considered in any recovery plan. Recovery won't occur with poor grazing management. Although these crested wheatgrass strips do not develop into diverse systems; they are better than cheatgrass. When systems are degraded to such an extent that natives can't establish, how do we begin the recovery of lands in this poor a state?

We need to initiate processes that might lead to eventual return to native, healthy systems. Sometimes there is no possibility of returning a system to a native state so we should look at adding something of value to the system while recognizing that we can't restore it to its pre-disturbance state. It can help to just get a stable and worthwhile system established.

So there is a marked contrast between the effects of these similar grasses, introduced into different systems, but with very different results. There's a disturbance threshold, that once crossed, makes recovery difficult. The scale of this problem is depressing - it's huge. Was the process set in motion by grazing? These kinds of problems are usually associated with grazing but they can also occur without grazing. Grazing may accelerate the problem, but removing cattle in itself won't solve the problem once it is underway; we must also change the fire regime.

Some of these areas were critical winter range for pronghorns and mule deer. Now these animals are hanging around train tracks and potato fields because their old range is useless. Some areas can be grazed while others shouldn't be, and biologists aren't the ones who make these decisions. The American philosophy that "we can fix anything" is challenged by these kinds of problems. Irreversible changes in systems can and do happen.

If you take a pristine system of shrubs and grasses and throw heavy livestock grazing into it, the animals take out the fine fuel before the brush, maintaining the system at a middle state. We could not predict ahead of time whether Japanese brome or cheatgrass would become the problem invader. It's hard to predict which species will become problems in which habitats. Human impacts can also prevent fires - roads, drainage ditches, etc., but we usually find ourselves starting fires.

Strategies for Coping with Plant Invasions

Dr. Whisenant has used fire, chemicals, and mechanical strategies to kill invasive plants, but he seems to keep facing the same problems over and over. Why? Perhaps because we're treating the symptoms of these problems rather than their causes. Now he thinks carefully and asks lots of questions before attempting control strategies. He builds simulation models to design "management" programs (not "eradication"). Finding the weak link in a population offers the best chance of regulating that population in the long run.

We are treating the symptoms of these problems rather than their causes.

Biological Invasions in Fresh Water Ecosystems

David Wilcove
Environmental Defense Fund
Washington, DC

In fresh water ecosystems 28% of all amphibian species are at risk of extinction, along with 34% of all fish species, 65% of crayfish, and 73% of unionid mussels, and very few of these are on the endangered species list.

The most endangered ecosystems in the US - and the ones with the highest proportion of endangered species - are our fresh water ecosystems. They are also the ecosystems least well protected by existing laws. In fresh water ecosystems, according to The Nature Conservancy, 28% of all amphibian species are at risk of extinction, along with 34% of all fish species, 65% of crayfish, and 73% of unionid mussels, and very few of these are on the endangered species list. The government is very slow to list these species, compared to mammals and birds. And we also do a poor job of aiding recovery of those fresh water species that do manage to get listed. For example, only 3% of endangered mussels for which there are recovery plans exhibit stable or increasing populations.

Fresh water aquatic ecosystems in the arid portions of the West are analogous to island situations in that they have localized populations, tend to be isolated, and their species may lack anti-predator defenses. For freshwater ecosystems in general, habitat destruction, including modification of waterways by dams and diversions, is the number one threat, followed closely by exotic species. In some cases, exotic species may be a more serious threat than habitat loss.

About 70 species of foreign fish are now established in the US and an additional 160 or so have been transported within the US outside of their native ranges, mostly for sport fishing. Fisheries managers continue to pursue an aggressive policy of stocking and introductions, which is harming native aquatic biodiversity.

In 1991, there were 86 species of freshwater fish listed as threatened or endangered in the US. At least 44 of these were listed in part due to introduced fish, and at least 29 of those introductions were made for sport fishing, with 11 due to trout alone.

Introduced fish are also partly responsible for the dramatic decline of amphibians in much of the West because the introduced sport and bait fish eat the eggs and tadpoles of native frogs. Also, many hatchery fish contain a fungus which destroys the eggs of amphibians. State agencies are responsible for the introductions and each state is free to set its own policy with regard to species introductions. Who pays for these introductions? We, the taxpayers do.

In 1950, Congress passed the Sport Fish Restoration Tax, an excise tax on boat fuel, fishing tackle, etc., which is given to states for the purpose of sport fish enhancement. A lot of money is being spent on this. In fiscal year 1990, $154.7 million was spent, and in FY 1991, $184 million was spent. A significant fraction of this money is spent on stocking non-native species. In fact, more money is spent stocking non-native sport fish than is spent on restoration of threatened and endangered species of fish, mussels, and crustaceans.

A unified national policy is needed on aquatic introductions based on 4 principles: 1) baseline study prior to introductions, 2) liability for control efforts if there are negative impacts, 3) funding for follow- up studies, 4) neighbor state's approval for introductions. Opportunities should be sought to marry the objectives of fishing interests with restoration and protection of aquatic ecosystems.

For more information, see the report by the Environmental Defense Fund entitled "The Big Kill," available for $20 from Environmental Defense Fund, 1875 Connecticut Avenue NW, Washington, DC 20009 (Attention: Publications).

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The OTA Report and U.S. Policy on Non-indigenous Species

Phyllis Windle
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How much value do we place on diversity? How important is it to avoid homogeneity? Do we care about preserving heritage of US species and ecosystem integrity? What is our vision of the kind of world we want?

The zebra mussel problem spurred interest in aquatic invasions at the national level, sparking the production of a report on harmful non-indigenous species by the Office of Technology Assessment (OTA). OTA's aim is to make technical information accessible to Congress. Members of Congress are generally educated laypeople who don't take naturally to scientific information. Using existing information, OTA produces extensive review papers, smaller summary versions, and four-page concise summaries.

The rate of introductions of non-indigenous species does not grow in a linear way; instead there are pulses in introduction due to social, technological and other factors. A pulse occurred at the end of the Vietnam war that may have been related to soldiers returning to the US with exotic species, intentionally and unintentionally. We are seeing another pulse now as the US military returns from Western Europe.

For OTA reports, accuracy is more important than precision. They seek to report information that is both necessary and sufficient, and not much beyond that. Showing the distribution of high-impact species and maps that reveal state-specific and region-specific problems are used because members of Congress want to know whether a problem specifically affects their districts. Scientists often seem unaware of what constitutes important information for Congress to have. What's missing is sometimes more important than the high precision information that is available.

Values play an important role in making decisions about how to manage non-indigenous species. How much value do we place on diversity? How important is it to avoid homogeneity? Do we care about preserving a heritage of US species and ecosystem integrity? What is our vision of the kind of world we want? We're not just dealing with scientific data here - we're dealing with poetic and philosophical issues.

US Policies on Non-indigenous Species (NIS)

Some have expressed the concern that it may be a form of racism to believe that certain species don't belong in some places - something like xenophobia - a fear of foreigners just because they're foreigners.

There are swiftly and steadily rising numbers of non-indigenous species. We're not eliminating any old ones as we keep adding lots of new ones. About 200 new species have been initially introduced or detected since 1980, and at least 60 of these are already causing harm or are expected to cause harm. Some fear that we could be in for a major crisis - analogous to the "body burden" for chemicals - when will it just become too much for the system to handle?

A Policy Primer

Formal laws come from all three branches of the federal government. From the legislative branch, come the federal statures and international treaties ratified by Congress. From the White House come executive orders and federal regulations that executive branch agencies use to turn laws into practices. From the Courts, come major judicial decisions that reinforce or change policies.

One White House directive came from President Jimmy Carter, whose 1977 executive order to restrict the introduction of exotic species into natural ecosystems was largely ignored and never implemented. The Supreme Court has made a few significant decisions including a 1986 ruling that allowed the state of Maine to ban all imports of bait fish from non-indigenous sources. This decision was important in that it implied that a state's interest in keeping out invading species would be allowed to override the interest of free interstate trade.

We could be in for a major crisis-analogous to the "body burden" for chemicals-when will it just become too much for the system to handle?

In general, international law is weak in comparison to national laws in this area. There are seven multilateral or bilateral treaties that relate to non-indigenous species (NIS) and another seven that indirectly affect NIS by dealing with habitat and other related issues. The Global Agreement on Tariffs and Trade (GATT) seeks to eliminate barriers to free trade and has spawned disputes over whether some quarantines are being used as protectionism not as legitimate quarantines to reduce biological invasions. Also, GATT may sidestep or override national environmental laws, such as the recent ruling that Mexican tuna caught with dolphins should be allowed in the US.

Federal laws related to non-indigenous plant species include the Federal Seed Act, the Federal Plant Pest Act, and the Federal Noxious Weed Act. There is some question about which laws apply to this issue - The National Environmental Policy Act (NEPA) and the Endangered Species Act (ESA) have not been large players in this arena. They are largely silent on exotics and have never been applied to NIS.

The Federal Noxious Weed Act and The Lacy Act use a "dirty list" approach -- they list hazardous organisms and restrict them. They could use a "clean list" approach, shifting the burden of proof by requiring those wanting to bring in exotics to prove that they will not be harmful. Windle is skeptical of this approach because of the huge outcry that has resulted when similar approaches have been suggested. Still, the current approach has severe limitations. It is very difficult to get a species on the "dirty list" in a timely manner - before the problem gets out of control. This is due to many factors including the time required for the public review process, inertia, etc. Also, the existing laws leave a lot of discretion to the agencies. In addition, under current federal law, there is no provision for legal suits if agencies fail to perform, such as has been the case under the ESA.

The US Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) uses a strict definition of "noxious weed" which includes only agricultural weeds; they cannot stretch it to cover weeds that invade natural environments like the Everglades. Scientists want to make this change in the law to cover natural areas.

Should we tinker with existing legislation or seek a radical departure from current system? Should we use different risk levels, cost/benefit analysis, risk analysis, safe minimum standards to make our best decisions?

The regulation of genetically engineered organisms is relying on current law; no new laws have been passed to deal with this relatively new phenomenon. But some may fall through gaps in existing laws -- like non-indigenous species do. How are these NIS and genetically engineered organisms related? First, there is a mismatch between the levels of risk and the rigor of review, i.e., genetically engineered organisms have been subject to far more rigorous review before release. Second, they are both about the unexpected consequences of moving organisms to a new environment. And third, there is no commonly accepted method for evaluating high risk introductions of either kind.

Each agency has its own policies on NIS and they allocate their own money. Twenty-one agencies currently undertake activities related to non-indigenous species, causing much complication. In addition, each state has its own policy, and even within each state, the approaches of the fish and wildlife department may differ from the approach of other departments with responsibilities in this area.

APHIS uses a strict definition of "noxious weed" which includes only agricultural weeds; they cannot stretch it to cover weeds that invade natural environments like the Everglades. Scientists want to make this change in the law to cover natural areas.

Phyllis Windle says that the moral is that there are many different ways to tackle this problem: federal policy is not just the statutes but includes local ordinances, state laws, local judges, district rangers, etc. There are a variety of ways to intervene in this process that can make our approach to NIS more effective.

How much biological invasion amounts to too much too fast? What we are experiencing is clearly too much too fast. There is currently a 14% annual increase in acreage covered by noxious weeds in the US. Is homogenization destined to be a trait of our times? How much do we value biodiversity?

"For one species to mourn the death of another is a new thing under the sun" -- Aldo Leopold, *Sand County Almanac*

Discussion comments

Regarding the national political process: The laws on this subject need to be changed. We also need to allocate more money - Congress now allocates just $400,000 to do something about domestic weeds (and $200,000 is preallocated to other things). The trend in Congress is that appropriations committees have grown in power compared to the large topic-oriented authorizing committees; apply pressure there. It might work to reform current legislation through the 1995 Farm Bill while building support for more sweeping legislation on this topic. The costs of prevention are so much lower than the costs of responding after the fact; why isn't this argument effective on Congress and the public in regard to allocating resources to this problem?

Regarding state and regional approaches: There seem to be some recent changes in the philosophy of state fish and wildlife agencies as they become more interested in nature conservation and somewhat less in sport fishing and hunting. This may not be true everywhere, and the extent differs. The Great Lakes regional approach has great promise.

Figure 26.1. State by State Distribution of Some High Impact Non-Indigenous Species

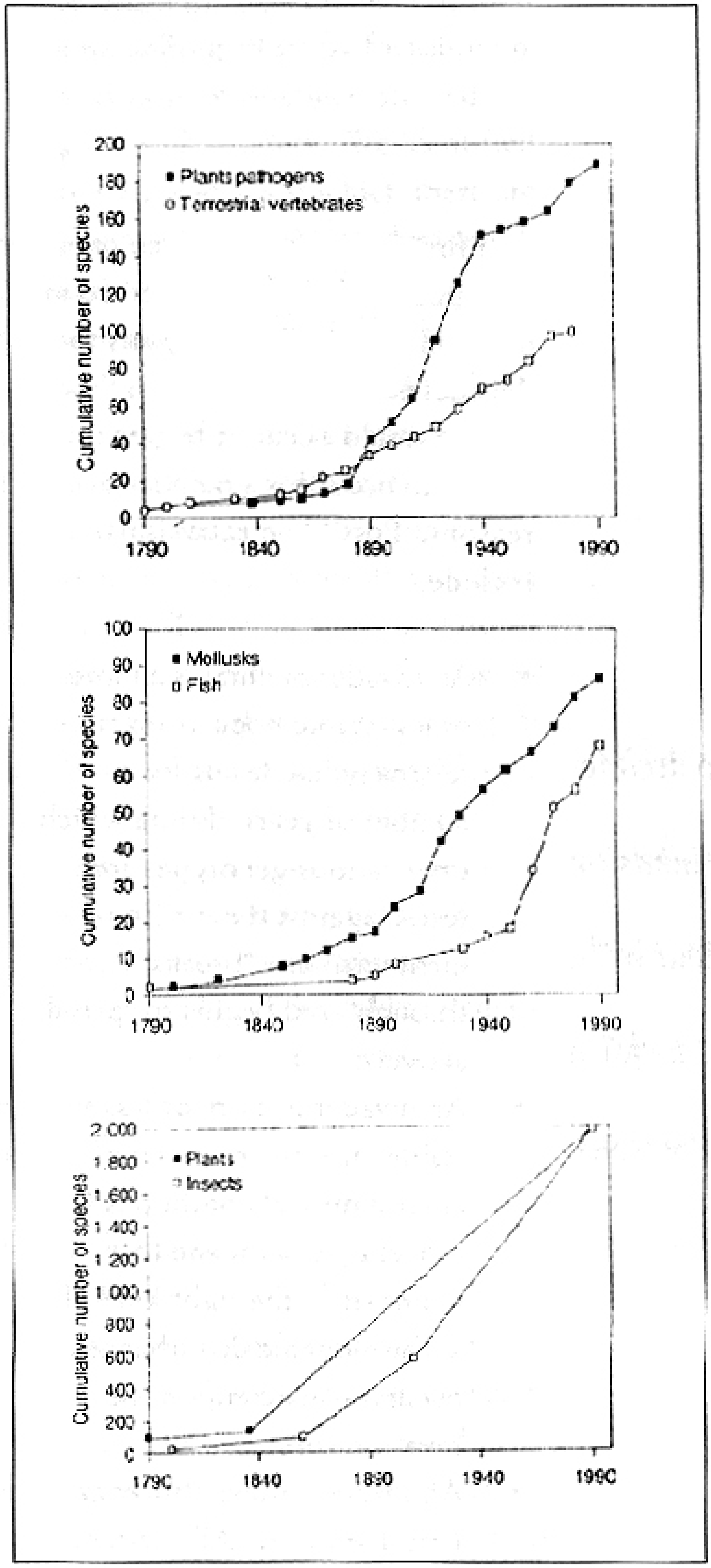

Figure 26.2: Estimates of Cumulative Numbers of Non-Indigenous Species of Foreign Origin in the United States

Appendix 1

Biological Invasion Research Issues Working Group Report

Our first discussion centered on the apparent lag phase observed in many invasions. Lags of years to decades early in the invasion process could occur or be perceived to occur for a number of reasons. Possible mechanisms include:

Lags of years to decades early in the invasion process could occur or be perceived to occur for a number of reasons.

- An invader maintains a more or less stable population at relatively low levels for a number of years, during which time various genotypes are tested against the environment until one "breaks through" and begins to spread actively.
- An invader is more or less stable until the right set of environmental conditions (a wet year, a hurricane that opens sites, the right kind of anthropogenic disturbance) occurs - whereupon the invasion spreads.
- An invader grows slowly at first due to the "Allee effect," many populations grow slowly at low densities due to difficulties in finding mates (for plants, pollinating successfully). Once a threshold population size is reached, normal exponential growth begins.
- Normal exponential growth can easily be interpreted as containing a lag phase; population could grow more or less continuously, but not be noticed until the last doubling or two makes it obvious.

While the first case has been discussed widely (and is possible), none of us is impressed that there is evidence for its importance. That's somewhat encouraging, because the fourth case can be identified if monitoring is adequate, and the second and third are at least potentially identifiable if enough is known about the species and system.

We then discussed how the most damaging invasions could be predicted. All invasions represent change, but we are concerned most strongly with those that affect human health or wealth, ecosystem structure and function, and/or the biological diversity of natives, populations, species, communities, or landscapes. We are impressed with the progress that has been made in identifying which organisms are likely to become established if they are introduced, at least for some groups of organisms; we are particularly impressed with the potential for development of quantitative models that identify likely invaders. However, we need to go beyond that to identify the subset of invaders that should be controlled first, with the limited resources available (and the available resources will always be limited). To address this set of issues, we need to develop a sharper understanding of what makes communities either subject or resistant to invasion, and which interactions between invader and community can cause fundamental changes in biological diversity and/or ecosystem function.

Overall, it was the sense of the group that what we need is a combination of case studies (called 'anecdotes' when there are too few of them, or when they are one-sided), experiments, and models based on the fundamental dynamics of populations and communities. There was some discussion of trying to develop a "universal (well, at least global) model" that incorporates attributes of invaders, invaded communities, and the environment; there was agreement that while we cannot develop a model that is general across all invaders and ecosystems, there can well be generic models that have features in common for a very broad range of species and ecosystems.

We believe it would be rewarding to begin the development of such a modelling effort by focusing on a set of relatively well-studied groups of invaders. We identified several groups for which there are plenty of cases of introductions and invasions that are reasonably well documented as to failures as well as successes, for which there are ongoing introductions that could be evaluated experimentally, and for which we have some strong ideas of controlling mechanisms. These include: pasture grasses, insects used for biological control, crayfish, and upland game birds. An effort to gather information, synthesize, and predict invasions and their consequences could be rewarding for any of these groups; an interactive effort on several of them could move us towards the development of a generic model.

What we need is a combination of case studies, experiments, and models based on the fundamental dynamics of populations and communities.

We then turned towards considering what should go into the "environment" and "effects" portions of such models. For invaders that can alter ecosystem properties, we are interested in resources - both because their availability determines the success of invaders, and because invaders that alter resource supply (or its variation in space and/or time) thereby have ecosystem-level consequences. For plants, the major resources that need to be considered are water, light, and nutrients. Additionally, alterations in the fire regime or in the frequency and/or intensity of other disturbances affects the ability of plants to use resources, and so has ecosystem-level effects; changes in substrate stability can be similarly important. Introduced animals could alter a number of these resources directly. In addition, animals could alter ecosystems by being effective "engineers" - altering soils and or sediments by bioturbation, altering hydrology by controlling water levels (as beavers do). Finally, organisms that alter the trophic structure of an ecosystem, often by adding or removing a top carnivore, also alter ecosystems. When considering the possibility that an invader might alter ecosystems, the major questions are:

- What potential invaders (or types of invaders) could alter the availability of limiting resources?
- What systems could be affected substantially by an alteration in the supply of a particular resource?
- What native species already present in an area affect resources more or less as the invader would? If such native species exist, invasion may be less likely; much more solidly, an invasion would be less likely to alter ecosystem structure and function even if it succeeded.

Overall, we agreed that while identifying those invasions that are likely to alter ecosystem structure and function is difficult, we do have both theory and experience to bring to bear on the problem, and can hope to make substantial progress. In contrast, predicting the effects of invasion on biological diversity is more difficult, in large part because idiosyncratic interactions are likely to be important. Certainly any invader that alters ecosystems is likely to affect diversity - but many that do not change ecosystem processes appreciably could still affect diversity. Is there a way to construct anything but idiosyncratic models about this phenomenon?

The key to a predictability may lie in identifying the resources that generate (or permit) diversity in different ecosystems. Where resource levels control diversity, alterations in ecosystem dynamics and diversity are likely to go together. Where the composition of the plant community controlled more by the availability of sites for seed germination and establishment than by factors influencing seedling or sapling growth rates, an invader that alters the number or nature of such sites could affect composition and diversity substantially without changing productivity, nutrient cycling, or hydrology directly. Other topics that arose in our discussion but were not resolved include:

- Can we encourage ecosystem restoration in degraded and invaded systems by establishing long-lived organisms, and using their effects on resources to encourage colonization by desirable native species?
- Can we manage disturbance regimes in a way that encourages colonization by natives and works against particular invaders?
- How can we determine (rationally) the utility of toxicants in the control of destructive introduced animals? Many North Americans shrink from this prospect - but we know that the costs (economic and environmental) of some invaders are substantial, and if toxicants work to control them, there may be instances in which their use is appropriate.

Similarly, how do we weigh the direct and indirect effects of pesticides versus biological controls, when both are employed on introduced organisms in near natural ecosystems?

The costs (economic and environmental) of some invaders are substantial, and if toxicants work to control them, there may be instances in whcih their use is appropriate.

Appendix 2 A Draft Model Law

Prevention of Harm by Non-Indigenous Species Act

a draft text for discussion

Approximately 4500 species in the US were non-indigenous, including 200 NIS introductions in the last 10 years.

Introduction

Increasingly, people have come to recognize the local, state, national and global economic and biological implications of biological invasions - the introduction of species where they do not occur naturally. Analysis of recent news articles shows an increasing awareness of the concept of a species being indigenous or non- indigenous, and of the harm caused by non-indigenous species (NIS).

Congress recognized the need to understand the problem of harm by non-indigenous species when it directed the Office of Technology Assessment (OTA) to evaluate and report on the topic. OTA produced a superb 1993 report finding that approximately 4500 species in the US were non-indigenous, including 200 NIS introductions in the last 10 years. Harmful Non-Indigenous Species in the United States (OTA, 1993).

Concern over non-indigenous species has recently surfaced in the interstices of federal law. The controversial 1994 crime control bill included a little-noted provision aimed at reducing the introduction of alien species to Hawaii, which has been especially hard hit by alien species introductions. Section 320108 of the act establishes a law enforcement task force, under the direction of the Attorney General of the United States, to

A. facilitate the prosecution of violations of federal and state laws relating to the conveyance, sale, or introduction of non- indigenous plant and animal species into Hawaii; and
B. make recommendations on ways to strengthen federal and state laws and law enforcement strategies designed to prevent the introduction of non-indigenous plant and animal species.

The task force is required to report to the Attorney General, Secretaries of Agriculture and Interior, US Senate Committees on the Judiciary and Agriculture, Nutrition and Forestry, and US House Committees on Judiciary, Agriculture, and Merchant Marine and Fisheries. Its report must assess

A. the progress of its enforcement efforts; and
B. the adequacy of existing federal laws and laws of the state of Hawaii that relate to the introduction of non-indigenous plant and animal species.

The issue of harmful NIS is ripe for thoughtful consideration and for development of wise policies.

The AGCI Conference on Biological Invasions as Global Change

From August 17 to September 2, 1994, a group of twenty five biologists, along with a few economists and lawyers, met under the auspices of the Aspen Global Change Institute to consider biological invasions as a kind of global change. The group was led by Drs. Peter Vitousek, Carla D'Antonio and Lloyd Loope. It included biologists from Australia and New Zealand - countries with major biological invasion problems.

Draft Model Act

One of the products of the conference was a sketch for a model act to reduce the rate and scope of harm from non-indigenous species. That sketch follows. It is still at a highly preliminary stage. The group is currently engaged in a process of drafting to produce a more refined model act.

While many introductions are beneficial- modern human society is largely dependent on non-indigenous crops- many others have brought substantial economic and environmental costs.

Four Questions

Laws regarding harmful NIS introductions must respond to four central questions:

First, who has responsibility for identifying NIS invasions, and where is information on the nature and scope of invasions collected?

Second, who has responsibility for responding to harmful NIS invasions, and what kinds of responses are encouraged or allowed?

Third, what processes and standards are used to assess proposed intentional introductions of NIS?

Fourth, what kind of follow-up is conducted after efforts to respond to invasions, or following intentional introductions, to assess and understand the actual impact of NIS on other species, on ecosystems, and on industry?

This model act makes an initial effort to deal with these central questions and a host of related issues. It is intended to serve as a working model for any country interested in adopting or revising strategies that address non-indigenous species invasions.

Prevention of Harm by Non-Indigenous Species Act

a draft text for discussion

I Statement of Purpose

II Definitions

III Prevention of NIS Introductions at Non-US sites; Exclusion at US Borders

IV Interstate and Intrastate Shipment; Special Pathways

V Release Review

VI Response to Biological Invasions

VII Dispute Resolution

VIII Research & Data

IX Education

X Liability for Releases

XI Support for State and Local Initiatives

XII Intentional Exports

XIII Funding

XIV Genetically Engineered Organisms

XV Agency Assignment of Responsibilities

Chapter I

Statement of Purpose

Human activity moves species from place to place at rates that are without precedent in the last tens of millions of years. The consequent establishment and spread of vast numbers of non-indigenous species (NIS) into entirely new regions represents a substantial global environmental change, one that alters both managed and wildland areas worldwide. While many introductions are beneficial - modern human society is largely dependent on non- indigenous crops - many others have brought substantial economic and environmental costs. Moreover, many invasions by NIS are irreversible on time scales far beyond those of most other ongoing global environmental changes.

Spreading populations of NIS interact with other components of human-caused global environmental change. Alterations in land use facilitate the success of many NIS - but many invaders in turn drive further changes in terrestrial and aquatic ecosystems, some of which favor additional NIS. The ongoing epidemic of extinction is driven in part by the spread of NIS; species of plants and animals that are unique to particular regions of Earth increasingly are replaced by a more homogeneous biota containing many NIS.

Many human introductions of NIS have been accidental, including plant pathogens brought in with contaminated soils or nursery stock, weed seeds brought in with crop seeds, and a wide variety of organisms that stow away on ships and airplanes. A number of domestic plants

and animals have escaped to the wild. Finally, many NIS now recognized as harmful were introduced deliberately, for direct human utilization, as ornamental or domestic plants and animals, for sport fishing or hunting, or as agents of biological control for other NIS.

Introduced organisms have had a wide range of impacts throughout the world on human health, agricultural and grazing lands, fisheries and waterways and the functioning of wildland ecosystems. Impacts can be economic, or ecological including altering ecosystem processes that sustain natural and managed systems and reducing native biological diversity. The global spread of infectious disease is the most familiar of the direct human impacts of NIS. An example of an economic impact is the introduction of two mollusc species, the Asian clam (Corbicula fluminea) and the European zebra mussel (Dreissena polymorpha) into North American waterways. These accidental introductions have cost the U.S. power industry and local municipalities hundreds of millions of dollars due to waterline clogging, interruption of cooling systems and increased pipe sedimentation and corrosion.

Existing laws, policies, and control procedures are inadequate to prevent the introduction and spread.

The cost of introduced organisms in relatively natural areas is better estimated by irreversible losses to the world's biological diversity and the alteration of ecosystem processes. The introduction of NIS fish species for sport fishing, biological control, and through accidental releases is a significant factor contributing to the decline of 60% of the more than 250 fish species that are currently rare or threatened with extinction in the United States.

Fundamental changes in ecosystem processes in natural areas and on agricultural and grazing lands can also result from NIS. Fire- promoting grasses have been moved both deliberately and accidentally around the globe and where established have led to increased occurrence of fire. For example, fire frequency in extensive areas of western U.S. rangelands has changed from one fire per 60-110 years to one fire every 3-5 years in response to the invasion of sagebrush shrublands by the European grass Bromus tectorum (cheatgrass). Because native species in these habitats cannot tolerate frequent fire, over 100 million acres of land has been converted from perennial shrubland to low diversity stands of cheatgrass.

Recurrent fire in these systems has led to loss of soil organic matter and reduced rangeland productivity, decreasing the ability of western rangelands to support either livestock or wildlife. The conversion of structurally diverse forests and shrublands to grasslands maintained by introduced species and fire is occurring worldwide and has been projected to lead to drier local climatic conditions with potentially significant regional consequences.

The many examples of occurrence of harmful NIS from throughout the world demonstrate that existing laws, policies, and control procedures are inadequate to prevent their introduction and spread. The purpose of this legislation is to create a unified NIS law that will:

- help to identify and prevent the introduction of harmful NIS
- facilitate introduction of beneficial NIS
- provide a comprehensive management strategy for harmful NIS that have already been introduced or that will become established in the future
- establish liability provisions for actions that lead to release of NIS, in order to make individuals, organizations, and government agencies bear the burden of the harm they cause, and
- create research, education, monitoring and database management programs to support NIS management efforts.

Chapter II
Definitions
For the purposes of this Act, terms shall be defined as follows:

Agriculture means the practice of producing crops or raising livestock.

Benefit means positive economic, environmental, and/or health effects.

Control means the prevention of spread of progeny of a non-indigenous species.

Cost means negative economic, environmental, and/or health effects.

Disturbance means a disruption, human-induced or otherwise, of an ecosystem.

Ecosystem means the sum of biological organisms in an ecological community considered together with the non-living factors of the environment as a unit.

Ecosystem processes means the transformation and flows of energy, material, and species among the component parts of the ecosystem.

Eradication means the act or process of eliminating an undesirable species.

Established means the condition of a non-indigenous species that has formed a self-sustaining free-living population in at least one location outside its natural range.

Feral means free-living animals that have escaped domestication or that are descended from domesticated ancestors.

Horticulture means the practice of cultivating flowers or ornamental plants. It may also include small-scale gardening of fruits or vegetables.

Hybrid means the offspring that result from the mating of to different taxa.

Indigenous means a species within its natural range or natural zone of dispersal, i.e., within the range it could have or would have occupied without direct or indirect introduction and/or care by humans. It excludes species descended from domesticated ancestors.

Synonym: *native*

Intentional introduction means all or part of the process by which a non-indigenous species is purposefully imported to a new locale.

Invasive means the capacity of a species to form self- sustaining, free-living, populations in an assemblage of species with which it has not previously associated, expanding its distribution. The species may or may not have been dispersed by humans.

Natural means occurring in conformity with the ordinary course of nature, outside the influence of humans.

Non-indigenous means a species present outside its natural range or natural zone of dispersal; includes all domesticated and feral species and all hybrids except for naturally occurring crosses between indigenous species

Synonyms *alien, exotic, non-native*

Pet trade means the practice of introducing animals for pleasure rather than utility.

Quarantine means the process of containment of an organism to prevent or limit the spread of potentially harmful NIS.

Release means the intentional introduction of a species into a free-living state for a specific purpose.

Risk means the probability of negative economic, environmental, and/or health effects.

Species means the basic unit of taxonomic recognition; refers to populations of morphologically and genetically similar individuals and may include infraspecific categories such as subspecies, variety, forma, or breed.

Substantial harm means a significant negative effect on a native species, native ecosystem, agricultural crop, or managed ecosystem.

Taxon (taxa, plural) refers to any taxonomic grouping such as species (including infraspecie categories), genus, family, or order.

Unintentional introduction means all or part of the process by which a non-indigenous species uses human-controlled transport systems to escape to a free-living state.

Chapter III
Prevention and Exclusion

A
Prevention (decisions made in the country of origin)

This section outlines guidelines to prevent the movement of problem species out of their country of origin. Prevention can be improved by bringing attention to the issue of non-indigenous species problems in the international community, by improving screens against harmful introductions, and by encouraging safer locations for study of the life history and ecology of certain species. Consistent with the spirit and purpose of this Act, it is the purpose of this section to broaden existing prevention and exclusion programs to protect explicitly natural as well as agricultural and other managed systems.

1. *Raising International Consciousness*

It is a foreign policy goal of the United States to elevate awareness in the international community of the threat posed by biological invasions to natural and managed ecosystems throughout the world. To this end, the United States encourages agencies of the United Nations, such as the FAO or UNEP, to assist countries by promoting research on and control of potential pests in their countries of origin. Adherence to the terms of agreements such as the International Plant Pest Convention is strongly endorsed. [Query: Is there a role for USAID?

2. *Preventing Undesirable Exports*

It is a U.S. foreign policy goal to encourage each of the world's nations to establish screening agencies with the authority to inspect all intentional species exports and to catch accidental "hitchhikers." The U.S. discourages the export of species identified on an international "dirty list" developed by the U.N. agencies identified in Section B (or by IUCN?). The U.S. recommends that those same agencies develop protocols for minimizing risks from unintentional international transport, including, especially, risks from ballast water releases.

3. *Screening Facilities*

The United States encourages the United Nations to establish research centers in the world's major biogeographic zones for the study of species native to each region that have become pests elsewhere and to develop screening procedures for native and other species prior to their intentional introduction elsewhere. (Permits to import species not on the "clean list" described in Chapter III, Part B, section 3, may not be issued until the proposed species has been screened by the appropriate lab.) [Unresolved: Is research appropriate, or would it be better to call for an international information network? Are facilities prohibitively expensive? Who should pay? U.N.?, exporting country?, exporting company?, importing company?]

4. *Sanctions*

Several sanctions are authorized to ensure compliance with the intent of this law. For example, shipments arriving at the destination that do not meet established criteria for hygiene may be destroyed or returned to the country of origin at the expense of the exporter. Countries that repeatedly fail to enforce export hygiene standards may be denied the right to export certain high-risk products to any country that chooses to deny entry. [What authority exists here? How does GATT affect this section? What about non-flag carriers?]

B

Exclusion (decisions made at the border of the importing country)

It is the purpose of this section to prevent the importation of unwanted species. The process involves inspection of imports that may harbor NIS at the port of entry.

1. *Authority*

This Act authorizes the establishment of an agency (the Agency) with the authority to prevent the entry of unwanted species into this country. Agents are given the authority to hold or deny entry to all shipments which, in their judgment, may contain species subject to this Act. The agency must develop adequate scientific

support to identify problems in shipments, and it must develop guiding policies (e.g. lists, screening criteria) on which to base decisions, including the issuing of permits for importation and for release from quarantine (see Chapter V).

2. *Intentional Importation*

All intentional importations are subject to inspection. All species allowed into the country must be either on a "clean list" or admitted subject to a permit based on assessment of agricultural and environmental criteria. Species without a permit and species on a "dirty list" developed by the Agency shall be denied entry. (Limited importing of "dirty" species will be allowed under permits issued for scientific research.)

3. *Unintentional Introductions*

Shipments containing unintentionally exported species ("hitchhikers") detected at the port of entry will be denied entry unless the species occur(s) on the "clean list".

4. *Permits*

Species not on the importing country's "clean list" will be allowed entry into the country subject to the terms of a permit issued by the Agency (see description of permit process in Chapter V). In addition to the state of knowledge regarding the organism, the permit application shall describe the terms of the importation, including description of proposed evaluation procedures and proposed use.

During evaluation, the species shall undergo additional review before a decision is made whether to allow release of the species to the environment (including, for example, use as a pet or in ornamental horticulture) or to add the species to the clean or dirty list (see Chapter V). Permittees who follow the terms of the permit are relieved of liability for any future damages caused by the proposed organism during and after review. [Unresolved: Is it wise to release the permittee from liability during review? What about faulty quarantine? We need a mechanism for delisting, etc.]

6. *Fees*

In return for the limitation on liability, the permittee shall pay a reasonable fee to cover the expense of the research required to evaluate the species. (See Chapter XIII on funding). In the case when an importer is unwilling to pay for the screening and review processes described in paragraphs D and E, the responsible agency will seize the shipment and destroy it or return it to the country of origin, at the expense of the exporter.

Chapter IV
Interstate and Intrastate Shipment; Pathways

Concern with the movement of species and the prevention of introduction of harmful pests has traditionally been defined in terms of political boundaries rather than relevant biological boundaries. Political units, of course, are the obvious source of rules to deal with NIS. But species are properly conceived of as "non-indigenous" when they are alien to the ecosystem - not the political unit - in question. A law should include procedures and guidelines on movement of species between and within smaller political units such as states and counties.

A law must also take account of the full variety of possible pathways for unintentional or unapproved intentional introductions of NIS. One major pathway is the mail. Provisions must allow for adequate inspection of parcels moving internationally and between states to avoid a huge gap through which NIS can easily pass.

Chapter V
Assessment of Proposed Intentional Introductions of Non-Indigenous Species

As recognized in Chapter I, NIS offer substantial economic, recreational and aesthetic benefits, but have the capacity to cause substantial environmental and economic harm. Therefore, the costs and benefits of intentional introductions must be carefully evaluated and safe standards must be established. It is equally important to exclude harmful introductions and to allow appropriate beneficial introductions.

Introductions should be denied if they pose risk of substantial harm to indigenous species or native ecosystems, regardless of potential benefit.

The appropriateness of initial or successive introductions depends on the possibility, probability and consequences of environmental and economic effects. The potential benefits and risks over time must be weighed, resulting in a range of possible categories of absolute or conditional approval or denial for introductions. Successive introductions should be granted the benefit or barrier justified by the prior review, so that commerce may commence and resources may be properly allocated by authorities reviewing proposed introductions.

This chapter sets out general principles for assessing the benefits and risks of introducing non-indigenous species. It suggests that such assessment must be based on sound science, and be formal, public, and subject to review and appeal. This chapter offers a range of suggested categories of approval or denial.

A Review of Intentional Introductions

1. *General Principles for Release*

The assessment of costs and benefits of release is difficult because of the complexity of natural systems and inherent uncertainty in prediction. Nonetheless, responsible assessments are possible.

Benefits and costs are not necessarily evenly distributed. For example, the benefit of a particular NIS may accrue to a different group than the cost imposed by changing an ecosystem.

Different kinds or organisms have different probabilities of harm, and different ecosystems have different vulnerabilities to invasions. Assessments must be made about particular proposed NIS in the context of introduction to particular ecosystems.

New introductions require a rigorous assessment of desirability. Before introduction of new NIS the following information must be gathered and submitted in a proposal to an appropriate review board identified in a particular agency. This information will serve as the basis for review.

a What is the reason for the proposed introduction?

- Is there an indigenous species that will serve the same purpose?
- Is there an alternative mode of action or control that will achieve the same goal?
- If the proposed introduction is to control another NIS, how much harm is the existing NIS causing?

b What is the record of prior releases and outcomes?

- Has this NIS been released before?
- What happened after prior releases?
- Require preliminary assessment of prior releases that are known but not previously researched (both those considered successes and those considered failures) - e.g. the Julien catalog.

c Prediction of possible impact

- Assessment of possible impact must be made across biological, temporal and spatial scales. Assessments must include consideration of space, time and biological (ecological) dimensions at least one level greater than the level of immediate impact.

Species attributes

- persistence
- capacity for increase and spread
- virulence
- host specificity
- taxonomic groups / presumptions
- habitat specificity
- phylogenetic similarity to indigenous species
- Issue: harm to indigenous gene pool

Habitat attributes

- similarities and differences of habitat or origin and habitat of introduction
- climate
- vegetation type and land use patters
- fire and other disturbance regimes
- description of other habitats where NIS introductions have established, and consequences
- requirement of assessment of habitat at one greater level of generality than the focus of introduction

Potential harm

- What is the potential harm if the NIS spreads?
- What are the long term implications for the introduction?
- What hypothesis about species relationships and/or ecosystem function is being tested by this introduction
-

Possibility of mitigation

- What is the possibility for mitigation of harmful impacts if the introduction is allowed to proceed?

2 Criteria & Assessment

The potential benefits must outweigh the potential risks as measured by the probability of invasion and expected harm from the invasion. Both benefits and risks must be established at a level of reasonable accuracy and based on sufficient evidence.

Decisions must be made in light of the spatial, temporal, biological and economic dimensions identified above. Assessments must consider benefits and costs in the short, mid and long term (e.g. 1, 5, 30 and 100 years).

Decisions should take into account the principle of sustaining ecosystem integrity. Introductions should be denied if they pose risk of substantial harm to indigenous species or native ecosystems, regardless of potential benefit.

Thus, for example, the use of alien organisms to control native pests should be strictly prohibited unless a compelling reason can be offered.

3 Levels of Approval

The relevant board should have the power to issue contingent and limited approval for introductions. We recommend that categories of approval or denial that take account of:

- Different levels of biological organization, starting with species, including more specific or local levels, such as distinct populations, and broader levels, including genera or families.
- Geographic concerns
- Time concerns
- Different levels of ecological organization, including local stands, communities, ecosystems; trophic relationships; and habitat process and process modification relationships.

Preliminary suggestion of possible categories include:

a *Black List*

- absolute ban; the traditional black list
- ban on introductions in certain locations

b *Gray List*

- ban on unassessed gene pools of species where other gene pools of the species have been introduced
- approval for one time introduction with required follow-up
- approval for repeated introduction in a particular location
- approval for introductions in new locations of species previously introduced elsewhere

c *White List*

- absolute permission; no further review required for additional introductions

d *Further Information Required*

- denial pending collection of information on
- prior introductions
- behavior in native ecosystem
- controlled testing

4 Assessment of Proposed Introductions by a Board

One or more boards should be established to review proposed NIS. The number and scope of the boards should be a function of varying requirements in expertise, varying public, commercial, and government interests, and workload considerations.

Each board should include expert, public, commercial and government interests. Experts might include biologists and resource economists. The public might include environmental organizations, NGOs, and private citizens. Commercial interests might include agriculture, horticulture, recreation and the pet industry.

The board must respond within a fixed period of time (e.g. 90 days). The board must explain its decision in writing. Decisions should be made by a substantial majority of the board, but allow for affirmative action in the face of modest dissent. Dissents must also be in writing. For example, affirmative action might be allowed based on the vote of 10 of 12 board members.

Decisions should be subject to review on appeal, either through formal reconsideration, or by a second body.

5 Follow-up Requirements

Every intentional introduction is a hypothesis testing experiment, requiring follow-up (an opportunity to learn more).

Intentional introductions of risky NIS must include follow-up monitoring and reporting requirements.

Chapter VI
Response to Invasions During and After Establishment Phase

Concerns and responses to NIS are variable depending upon the status of the target or potential NIS. These can be divided into Stages as follows:

Stage 1. NIS not present in area of concern - response consisting of detection and interception;

Stage 2. NIS detected at entry point but has not escaped into area of concern - response limited to quarantine or disposal;

Stage 3. NIS introduced or escaped into area of concern, but reproducing populations are not established;

Stage 4. NIS established and reproducing but population size remains small and localized;

Stage 5. NIS established and in rising limb of expansion into new habitats;

Stage 6. NIS in asymptotic phase of establishment, or fully established, into most areas suitable for inhabitation.

A Concerns, and Shortcomings of Existing System and Responses

Interception and quarantine efforts, no matter how well designed and executed, will fail in some instances, resulting in incipient invasions into environments dedicated to commodity production and/or resource and ecosystem protection (Stage 3). Other potentially invasive and harmful NIS are already present in the environment but, because they are in a slow growth phase or environmental conditions are not presently suitable, have not yet entered their exponential expansion phase (Stage 4). If detected, these are relatively susceptible to treatment and eradication, provided that information and institutional mechanisms allow rapid response. Finally, some invasions of NIS have reached the level where they threaten valuable or irreplaceable resources (Stages 5, 6), at which point impacts and the need for control is clear and warranted but they are likely less susceptible to treatment and eradication.

Under present circumstances, often no action is taken when incipient invasions of NIS could be “nipped in the bud”, simply because the NIS is not detected, no agency steps forward to initiate response, and/or information and expertise are not readily available to apply to the problem. Often no agency has been given an unambiguous mandate to respond within various jurisdictions, and legal authority for response is not clearly detailed in existing statutes. A common instance is that an invasive NIS is present on State or private lands and threatens adjacent “natural areas”, but departments of agriculture lack a clear directive to confront threats outside of agricultural lands. Furthermore, there is generally little agency awareness of the presence of incipient invaders and the need for early response. A rapid response is necessary so that we can move from reacting to disaster (with associated high costs and low probability of success) to timely, cost-effective action prior to reaching an unacceptable threshold of damage.

The justification for legislation directed toward NIS present within Areas of Concern can, thus, be summarized by the following concerns:

- The bureaucratic lags inherent in existing mechanisms are unacceptable in the face of a NIS capable of rapid spread;
- Current “goodwill” approaches (responses initiated by enlightened managers, acting on foresight but without legal mandate) have a high risk of failure if they lack institutional support and continuity;
- No adequate information support system exists which managers can readily apply to identified NIS problems;
- A categorical listing process for identified NIS is essential to legitimize response, particularly when threats are relevant across jurisdictional boundaries;
- There is a need for an unambiguous mechanism to evaluate and prioritize problems, assign responsibility and authorize funds.

B Biological Invasion Response Task Forces

To effectively deal with invasions once interception and quarantine measures have failed a Center for Harmful NIS Control will be established. The Center will serve as a clearinghouse for NIS database information and for coordinating the distribution of operating funds to the regional bodies described below.

Regional decision-making bodies will be formed to serve as conduits of information, provide risk assessment and priority regarding NISs, and to delegate responsibility and authorize funds to carry out actions. These bodies, or Task Forces, will be comprised of 8-12 representatives from regional and federal agencies responsible for resource management, and vital interest groups concerned with resource issues, including NGO’s, academic researchers, and resource industries. Task Forces will be set up on a State-by-State basis, except where resource concerns are broadly overlapping among States, and/or regional responsibility is mutually acceptable (e.g. New England, Pacific Northwest states, Great Basin states).

The role of a Task Force is to allow a fast-track response to emergency situations, and to provide an efficient mechanism of response to established, problem invasions. Requests for action will be made by petition, initiated from any reliable source (with validation from recognized institution or organization concerned with resource issues), including the Task Force itself. Risk assessment will be conducted using information provided in the petition, and other supporting information, and priority level will be based on criteria set forth in the following sub-section (Chapter VI, Part 3). Risk assessment will follow a 2-track approach. An emergency petition involving incipient invasions requires a positive or negative response within a 30 day period from the time petition is accepted. A second track will involve already established invasions, and action based on assessment of the threat posed to resources, regardless of whether or not the target NIS has potential for expansion.

The role of a Task Force is to allow a fast-track response to emergency situations, and to provide an efficient mechanism of response to established, problem invasions.

The Task Force will determine a Reasonable and Adequate Response to achieve the goal of NIS eradication or management at tolerable levels. This includes determining the costs of response, and authorizing distribution of funds from a Congressionally-approved Fund (see Chapter XIII). Although such authorization may take into account competing demands for response, determining the level of risk will be based only on scientific information and judgment, not on available funds. To provide comprehensive and consistent information, the Task Force will direct the establishment of a database on NIS’s in and adjacent to the management region, which will be updated on a regular basis.

The Task Force will delegate responsibility for action to an appointed Response Team composed of experts and practitioners, along with the authority to spend funds. The Response Team will also be responsible for intensified monitoring efforts within the region of the invasion, to quantify extent of the invasion and as a baseline for required, post-treatment monitoring of progress toward the desired goal. Additional research information required to determine degree of threat can be requested from the Response Team, or from other recognized experts through similar funding mechanisms. Once actions have been taken, the Team will assess effectiveness of response, and further action based on discussion between the Team and the Task Force.

When a decision to conduct action against a NIS is made, the Task Force will simultaneously assign responsibility and funds for conducting an information campaign within the target region. This education effort will facilitate public approval for action and will promote understanding of the threat and reduce the role of citizens as vectors of the NIS.

Each Task Force will meet annually to review non-emergency petitions, and to consider the status of the developing database on biological invaders. Listing of risk level of NISs and determining appropriate responses can be done at that time. Emergency petitions do not require a joint meeting unless this is deemed necessary. All Task Force members must review such petitions within the 30-day period, however, and must be involved in determining Response Team leaders and appropriate level of response. Listing decisions will be based on majority approval of petition decision. A mechanism for dispute resolution will be provided to allow public objections and input regarding listing and action decisions, as set out in Chapter XI.

C Determination of NIS Priority Level or Risk

Newly established or recognized problem NISs will be prioritized according to their impacts on valued indigenous species and ecosystems, on economic resources, and on the impacts that control measures are likely to have. Action will be taken only when careful consideration indicates the overall impacts will be less disruptive than allowing the NIS to go unchecked. Priorities will be assigned so that the fastest growing and most disruptive problems are tackled first, thereby minimizing the overall long-term pest-control workload. Thus, preference will be given to attacking incipient NIS problems and outliers of larger infestations first, next, preventing the expansion of larger infestations, and then to reducing the size of or, if possible, eliminating larger infestations.

Priorities will be assigned to a particular NIS listing as follows:

Level 1
Emergency Response
NIS has capacity to alter fundamental ecosystem processes; NIS can invade and dominate relatively undisturbed indigenous assemblages and reduce or extirpate local populations of native species; NIS known to consume or reduce quality of important crops or other economic resources; NIS is capable of transmitting pathogens to human populations or to designated Threatened or Endangered species; NIS shows any traits listed above and is actively reproducing, and evidence suggests that populations are growing rapidly;

Level 2
Emergency Response

NIS has potential to consume, parasitize, spread pathogens to, or otherwise detrimentally interact with indigenous species following natural or other disturbances; NIS can prevent or depress reproduction/regeneration of indigenous species, possibly leading to long-term changes in species composition; NIS presents purely cosmetic damage to economic species, or is not known to damage economic species but is taxonomically related to other pests; NIS for which long-term control or eradication can be accomplished at reasonable expense;

Level 3
Highly Justifiable Response

NIS population is small, possibly indicating an incipient invasion, but does not possess traits suggesting immediate epidemic expansion is likely; NIS is well-established, known to have moderate impacts on indigenous assemblages and ecosystems or economic resources, but is extending range; NIS associated with disturbed areas, but may interfere with restoration efforts; NIS for which long-term control or eradication can be accomplished at reasonable expense;

Action will be taken only when careful consideration indicates the overall impacts will be less disruptive than allowing the NIS to go unchecked. Priorities will be assigned so that the fastest growing and most disruptive problems are tackled first.

Level 4
Low Priority Justifiable Response

NIS for which long-term control or eradication can be accomplished at reasonable expense; NIS that colonizes only disturbed areas (e.g. abandoned fields, overgrazed lands) and do not expand into undisturbed habitats; NIS that is eliminated by indigenous species during succession or re- establishment of natural processes, e.g. fires, floods; Established pest on economic crops with minor or cosmetic impacts on products;

Level 5
Probable Non-Justifiable Response

NIS which numbers remain low or decreasing; NIS for which long-term control or eradication cannot be accomplished at reasonable expense.

Chapter VII
Dispute Resolution

A Handling Conflicts of Interest Between Jurisdictions

What should be done if one state wishes to introduce a non- indigenous species, but one or more adjacent states object?

Species may be introduced into a state for recreation, agriculture and forestry, ornamental horticulture, biological control, or the pet/zoo trade. Individuals, businesses, or agencies may initiate such a request, but the state's approval of a request for introduction should be made by a committee that represents private as well as local, state, and federal interests. If permission for an introduction is granted by a state, adjacent states have an interest in the introduction because of the possibility of escape from control and subsequent invasion.

We propose that all neighboring states be notified when a state approves a request for introduction of an exotic species. These neighboring states (and the state proposing the introduction) would constitute a panel that, upon receiving notification of the request, would hear the evidence and vote on whether to permit the state to proceed with the introduction. A simple majority would be necessary for the state to proceed with introduction. In the case of even-numbered panels, a tie vote would constitute rejection.

The purpose of this panel is to introduce regional perspectives into a state's considerations. Any one state may participate in several regional panels (depending on what its neighbors are doing), increasing the likelihood of communication about problems as they develop. Appropriate panels for Alaska and Hawaii might include those states that dominate their interstate commerce relationships. Many decisions may be considered pro forma and could be handled by a mail ballot, but at least all neighboring states would be aware of all approved introductions. When such an action involves moving an established or indigenous species from one part of the country to another, the appropriate agency in the federal government should be kept informed.

We do not think the federal government should receive special consideration in this process, particularly in cases involving introduction from another country, in which it has already had opportunity to assess overall suitability. At the state level, therefore, it should comply with regional interests. For instance, if the Forest Service wishes to introduce a species for biological control into a National Forest, it must go through the same request process and panel decision as any other land manager. There are existing precedents for this in the provisions of the Clean Air Act, the Water Quality Act, and the Coastal Zone Management Act. No entity should be able to force introduction (or extirpation) onto the lands of another entity, however. In other words, states cannot demand that federal land managers introduce or extirpate species on federal lands. The converse is also true.

B Handling Conflicts between Different Parts of the Public

Although neighboring states may have no objection to an introduction plan, parties within a particular state may be divided on the issue. Alternatively, parties within a state may differ as to the desirability of eradicating a particular non-indigenous species.

If an unanticipated problem arises after an introduction (such as the one that precipitated the Australian Biological Control Act of 1984), it should be the responsibility of the state committee to establish a protocol, after consulting with appropriate experts, for resolving both economic and ecological conflicts. Solutions may range from removal of the introduced species to temporary subsidies to the "injured" party, depending on the economic and ecological nature of the conflict. Information about this conflict should also be communicated to adjoining states.

C Handling Disputes about the Proper Use of the "Indigenous" Label

What should be done if within a given state, a dispute arises as to whether a particular species is indigenous?

When a group (or state) wishes to reintroduce or eradicate a species on government-controlled or private lands, another group may dispute the species' status as indigenous or non-indigenous,

respectively. It should be the responsibility of the group proposing the action to make its case; the state committee should decide which interpretation is correct after consulting appropriate experts. As outlined above, a majority vote of the adjacent states should also be obtained when proposing reintroduction of any indigenous organism into a state where it has been extirpated. A system for considering intrastate reintroductions should be constructed by each state. None of these provisions apply to introductions made to help with the recovery of a federal endangered species to avoid posing an additional burden to an already lengthy process.

Chapter VIII
Database & Research
A Non-Indigenous Species (NIS) Database

A database should be developed that contains information on species that have proven to be invasive and species that are proposed for introduction outside their natural range either by import or export. The database will be used as an information source and decision- support system for regulatory agencies, commercial enterprises, and educational institutions. The objectives of this database are to (1) provide information to assess the potential damage that might be caused by the species; (2) provide baseline information on invasive non-indigenous species; (3) provide information on ecosystems most susceptible to harmful invasion; (4) provide information on management of existing invasions and (5) provide a database for monitoring changes in geographic and environmental distribution.

The database should be developed and maintained by an international agency and updated by a corresponding federal agency in each country and should include the following types of information:

1. family;
2. genus;
3. species;
4. subspecific taxa;
5. common names;
6. native range and climatic information;
7. when and where introduced;
8. control strategies (including control strategies that have been ineffective in other situations);
9. information on problems that have occurred when introduced elsewhere;
10. potential to serve as host, vector, or pollinator of other harmful non-indigenous species;
11. key researchers & contacts concerning biology, management and control;
12. relevant bibliography;
13. species attributes believed related to invasiveness (e.g., physiology, nutrient requirements and reproductive biology);
14. attributes of ecosystems susceptible and resistant to invasion;
15. commercial values; and
16. any other relevant data.

This database should be compatible with other international databases, such as the International Union for the Conservation of Nature (IUCN). It is also desirable for this database to be linked to the GAP analysis and Natural Heritage databases.

Some procedure needs to be established for changing databases and maintaining credibility of information. The database should be available to anyone, but the ability to make entries and changes should be limited to the responsible organization. It is especially important that this information be readily available to the agencies responsible for early detection and control (refer to section VI).

B Monitoring and Detection

An active program should be created for the detection of new invasions and monitoring the status of existing invasions. This information will be entered into the database, relayed to the agencies that respond to invasions (see Chapter VI) and the agencies concerned with invasion pathways (see Chapter IV).

Funding should be provided for the development of taxonomic expertise necessary for the identification of all organisms. (see Chapter XIII)

C Support for Research

A specific program should be established to fund basic and applied research on invasive species and invasion pathways (refer to Chapter XIII for funding mechanism). These research activities should be directed at improving our ability to anticipate problems and manage existing problems resulting from non-indigenous species. Supporting research should focus on improving our ability to prevent unintentional introductions (e.g. detection of seeds, container fumigation, ballast sterilization). (see Chapter XI)

Research should focus on identifying characteristics of invasive species, identifying ecosystems susceptible to invasion, and determining reasons for spread. Other research should focus on developing control strategies for existing harmful non-indigenous species.

Chapter IX
Education

Education is often more effective than enforcement in achieving compliance with broad policies. This section outlines three premises on which we base educational efforts.

First, the government has the responsibility to distribute educational information based on sound scientific research. The goal is to facilitate collection and wide distribution of information on NIS in general, and specifically on mechanisms by which introductions of NIS may lead to economic and/or environmental damage. We suggest provisions for educational activities aimed at the general public, at Kindergarten through grade 12 school students, and at specific target groups for whom NIS are particularly relevant (e.g. the nursery and pet industries, travelers).

Second, the government has a responsibility to inform all concerned parties of the provisions of this Act and of activities or progress related to it. Explanatory brochures prepared and distributed to relevant groups will promote a clear understanding of the Act and its provisions. Also, there should be regular and widely distributed reports of actions taken and progress achieved, in order to maintain/increase public awareness of the problem and of the Act.

Third, the government has a responsibility to provide adequate training to personnel involved in carrying out the Act's provisions. Where formal federal responsibility encompasses federal employees engaged in quarantine, inspection, response actions, etc., sound training and support should also be available to state and local employees, volunteer groups, etc., when these are involved in activities promoting the overall objectives of the Act.

A Education About Prevention

Experience validates that most people will "do the appropriate thing" if they know what the appropriate action is.

1. An identified Agency will take the lead in making research and current problem species based information available by formatting such information into appropriate brochures, posters, video footage, public service announcements, touch screen presentations, etc., and then making them available at all ports of entry and border crossings. These materials shall be made available (at production and distribution cost) to airlines, cruise ships, trains, bus tours and other commercial transportation systems for presentation to their clients. Federal contract air travel suppliers will be encouraged through their contract provisions to show public service announcements as a part of their in-flight video presentations.
2. The Federal Government will initiate programs through its state, local, and NGO cooperators to inform local property owners of the problems and issues associated with non-indigenous species. As a part of this initiative the agency will provide these same educational and informational materials identified in section 1 to national organizations, associations (e.g., the Nurseryman's Association, Native Plant Association, Associations of Arboretums and Botanical Gardens, National Wildlife Federation, National Pet Shop Owners, International Association of Fish and Wildlife Agencies, National Audubon Society, and National Council of State Garden Clubs).
3. The Federal Government will also provide the information in section 1 in addition to a copy of regulations related to the NIS Act to all interstate and international transporters and shippers that transport non-indigenous species identified in this Act.

B General public education about NIS

The Agency will make research based information and information on current issues relative to this act available through regular bulletins, press releases, video clips to national television (CNN, Public Broadcasting, etc.) and print media (Gannet Publishers). The materials developed for distribution in section A.1. of this Act will also be made available to the general public.

In addition, the Agency will distribute specific research based information on non-indigenous species to the national network of Agricultural and Horticultural Extension Agents and Soil Conservation Agents.

C Local Involvement in monitoring and response

1. The Agency will establish a protocol guideline for distribution to local governments, organizations, landowners, land managers, and individuals who wish

to help control non-indigenous invasive species by species type and recommended procedure for that species.

2. The Agency will establish a screening protocol to identify and catalog into a national and regional databases people throughout the nation with expertise in identifying and controlling non-indigenous species and who are willing to share their expertise at the local level. This database of experts will be updated at least annually.

3. The NIS Act will authorize a volunteer program to be available to all federal agencies to provide logistical support in addressing non-indigenous species problems . The NIS Act will provide liability protection, training and certification for volunteers who participate in the NIS management program.

D Support for Education on NIS

1. The Agency will make all of its publications and informational- educational products available to educational institutions and teachers. These materials may be distributed through National organizations and professional societies (e.g. National Science Teachers Association, American Biology Teachers Association, Ecological Society of America, Natural Areas Association for Conservation Biology).

2. The Agency will create a Requests for proposals (RFP) Program for public agencies, not-for-profit organizations, schools, and for- profit organizations which have demonstrated expertise in curriculum development and which have a delivery system in place for distribution of the products on a regional basis considered a target population by NIS or on a national or international basis. The RFP will be focused on the development of model instructional materials and programs on non-indigenous species problems and issues which have a high degree of potential replicability in other relevant geographic areas.

E Training for Appropriate Federal Employees

1. The Agency will coordinate and fund interagency development and applications of a comprehensive training program (dealing with identification, handling, management, and communication about, non-indigenous species) for Federal employees who have a responsibility to interact with non-indigenous species. The Federal training program will also be made available to state and local government officials.

Chapter X
Liability for Releases That Cause Harm

There should be civil liability for both intentional and unintentional introductions. Depending on the level of culpability involved in the introduction, different levels of liability might attach, distinguishing the costs of control of harmful NIS and the costs of the harm they impose. This section must also address waivers of sovereign immunity and payment by the government for harms that result from its errors. In the current federal context, this part of any act would need to consider instances of multiple party liability for control and harms (such as Pittman/Robertson and Wallop/Brough programs).

Criminal liability should attach for intentional introductions intended to cause harm. In the most extreme form, criminal provisions would address threats from “bioterrorism”.

Chapter XI
State and Local Initiatives

This section outlines a program to provide funding for worthwhile research, management, and education projects involving non- indigenous species. Another funding program, similar in intent but very different in structure, is outlined in Chapter VIII of this model act.

The federal government cannot alone “solve” the problem of harmful non-indigenous species. Important research and education programs and control efforts have been undertaken by state and local governments, universities, private organizations, and private citizens. Individual states and communities should be encouraged to develop their own laws and policies to address these issues. We wish to encourage and support these efforts and, in particular, to stimulate new thinking and action on the topic of non-indigenous species. Accordingly, we recommend the establishing of a funding and technical support program.

Federal agencies should be authorized to set up competitive grants programs and cooperative agreements that would provide funding and assistance to individuals, public and private organizations, state and local governments, universities, and multi-state and multi- agency working groups for education, research and policy development and implementation, leading to control or elimination of harmful non-indigenous species. Special emphasis will be given to helping states or groups of states develop comprehensive state and regional programs to control invasive non-indigenous species. Each agency should be responsible for evaluating those proposals that focus on the land area, resources, or responsibilities under its control.

The participating federal agencies should, at a minimum, include the following: Department of Agriculture (SCS, APHIS, USFS, ARS); Department of Defense (Armed Services; Army Corps of Engineers); Department of Interior (Bureau of Reclamation, BLM, FWS, NPS, NBS, Bureau of Mines); Tennessee Valley Authority; Department of Energy; Department of Health and Human Services; Department of Education; National Science Foundation; Department of Transportation; and the Environmental Protection Agency. We suggest that independent grants programs be established in each agency unless there is a successful model for an interagency funding source. Agencies should also be authorized to provide technical assistance, if requested and where feasible.

Chapter XII
Exports

A law should be concerned with the export of indigenous species where they will be harmful. This principle was first captured in US law in an executive order on non-indigenous species signed by President Carter, and nominally still in effect.

Chapter XIII
Funding

This model law gives agencies additional responsibilities, e.g., for emergency responses to newly detected invasive species, for creation of complex international and national databases, for more thorough pre-release screening of proposed introductions, and for

managing established non-indigenous species. The problems faced by the federal interagency Aquatic Nuisance Species Task Force - delays in reporting to Congress, lack of staff, etc. - illustrate what happens when new programs are authorized without supplying funds for their implementation.

Also, federal and state officials commonly cite funding problems as an important element in their inability to plan ahead and to ensure successful agency programs on harmful non-indigenous species (NIS). This is especially the case for weed management on federal lands but also for programs related to fish, wildlife, and natural area management.

For these reasons, new sources of funding are required if harmful NIS are to be researched, evaluated, excluded, and controlled in ways that effectively protect agricultural, grazing, forest, aquatic, marine, and natural area resources.

The federal government cannot alone "solve" the problem of harmful non-indigenous species. Important research and education programs and control efforts have been undertaken by state and local governments, universities, private organizations, and private citizens.

A Principles

The following recommendations are based on several principles.

- First, those who benefit from the largely open global system for importing, releasing, and exporting potentially harmful NIS should pay for the public services their actions necessitate.
- Second, the amount of funds available for research, analysis, and control of NIS should increase with the number and/or risk of proposed and actual introductions.
- Third, funds for emergency action will always be required for organisms that slip through inspection and exclusion systems.
- Fourth, high priority management and control programs require steady, multi-year funding to prevent lapses of effort during which invasions can grow beyond the possibility of eradication or containment.
- Fifth, interagency cooperation is needed to ensure that no incipient or established harmful non-indigenous species fall through existing or new jurisdictional and management gaps.

B Recommendations
Permits and Permit Fees

All introductions of harmful or potentially harmful non-indigenous species will be subject to federal permits and the federal government will collect fees for issuing these permits. Permit fees to introduce "gray list" and "dirty list" species will be based on the relative risk of the organism being proposed and the amount of uncertainty surrounding its possible effects, as determined by groups of experts. That is, permits for highly risky organisms about which little is known will require the highest fees. Fees will be high enough to discourage spurious imports (e.g., biological control organisms for which there is no or little evidence of likely effectiveness), to stimulate caution regarding organisms known to be invasive elsewhere, and to fund additional research on organisms for which great biological uncertainty exists.

Fifty percent of permit fees (above processing costs) will be placed in the Non-Indigenous Species Research and Education Fund. These funds will be available for competitive research grants to individuals, public or private organizations, state and local governments or multi-

state or multi-agency working groups for education and research and policy development and for paying nominal honoraria to expert proposal reviewers. The remaining fees above administrative costs (50 percent) would be available for emergency use, including the activities of the Biological Invasion Response Task Force.

Permit applications will include a proposal, as outlined in a previous section. This proposal will include detailed plans for controlling organisms that escape confinement or cause unexpected harm, with an estimate of the likely cumulative costs associated with control and restitution of harm. Once the permitting agency and the applicant agree on the accuracy of this estimate, an equal amount of money will be set aside in an interest-bearing Non-Indigenous Species Escrow Account. This money can be released to the applicant 25 years after introduction unless publicly-funded control efforts were needed and their costs equalled or exceeded the amount in escrow. In that case, the applicant forfeits the amount required to fund the control effort. For estimated cumulative control and indemnification costs greater than $250,000, applicants can escrow 50 percent of the estimated cumulative costs if they provide proof of adequate insurance to cover the full amount.

Any importer that sidesteps the review and permitting process will be subject to criminal fines and/or imprisonment.

User Fees

The authority to charge user fees is expanded to agencies that deal with non-indigenous species and for purposes other than those allowed now. That is, all passengers, carriers, and shippers will be charged for port inspection and pest exclusion activities. Fees will be based on the probability that a given activity or pathway will intentionally or accidentally lead to importation and/or release of harmful non-indigenous species.

Also, voluntary and mandatory certification programs - like those in place for weed-free forage, triploid grass carp, and non-Africanized honeybee queens - could recover at least 95% of their associated public costs from private users. Additional certification programs could be instituted, e.g., for baitfish, disease-free fish and wildlife, weed-free, non-invasive birdseed, indigenous and non-invasive wildflower seeds and wildflower seed mixtures, and non-invasive ornamental plants. Fees for interstate or international movement of certified products should be higher than fees for materials moved locally. In some cases, certificates could take the form of product tags, suitable for educating retailers and consumers.

Excise Taxes

The federal government collects a variety of funds that return to the state for fish and wildlife management - Dingell-Johnson, Pittman- Robertson, and Wallop-Breaux funds. For example, ten to eleven percent manufacturers' federal excise tax is collected on firearms and hunting and fishing supplies. These funds are returned, in the next fiscal year, to states for fish and wildlife management projects.

This section explicitly broadens the availability of such funds for certain uses: 1) for projects that remedy harm caused by non- indigenous fish and wildlife (including introductions previously funded in these programs); 2) to control non-indigenous species in terrestrial and

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aquatic ecosystems; and 3) to conduct education programs. States that can document such broadened programs are automatically eligible for matching funds from the Non-Indigenous Species Research and Education Fund.

This section also limits the availability of such funds. No funds shall be used for the importation, introduction, release, or transport of non-indigenous fish and wildlife.

If documented shortfalls in funding for the prevention, quarantine and management of harmful non-indigenous fish and wildlife species exist five years from enactment of this law - as determined by task forces and state resource managers, the federal excise taxes described above shall be applied to sales of invasive, non-native plants and animals. Such organisms shall be determined jointly by federal, state, and industry officials. Revenues generated shall be equally divided among the federal Non-Indigenous Species Education Fund and federal aid-to-state funds.

General Funds

The funds and fees in this section are not intended to replace general funds available to agencies.

C Immediately Available, Modest Changes

Agencies dealing with non-indigenous species could present their annual budget reports to Congress so that work related to these species is readily identifiable.

The National Park Service and other federal resource management agencies could increase any entrance or user fees not at the congressional limit, with all of the additional funds generated used for resource management programs.

D Status of Current Law

The 1990 Farm Bill authorized APHIS to collect user fees for international port inspections, for issuance of plant health certificates, animal quarantines and disease tests, and export health certificates. The Land and Water Conservation Fund Act of 1965 authorized 7 federal land management agencies to charge entrance or user fees for certain services, at certain facilities. It has been amended repeatedly. Dingell-Johnson, Pittman-Robertson funds are based on a federal-state cooperative program managed by the Fish and Wildlife Service.

Chapter XIV
Genetically engineered organisms

This section will be necessary only if the principles for handling genetically engineered organisms are sufficiently different from the general principles for review of proposed NIS introductions to require special standards or procedures.

Chapter XV
Agency Assignment of Responsibility

The assignment of responsibility among various agencies will depend on the structure of each government. In the US federal system many agencies are likely to be involved with different aspects of a comprehensive NIS law.

Drafted by participants in the Aspen Global Change Institute Session on Biological Invasion as a Global Change August 21 to September 2, 1994

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