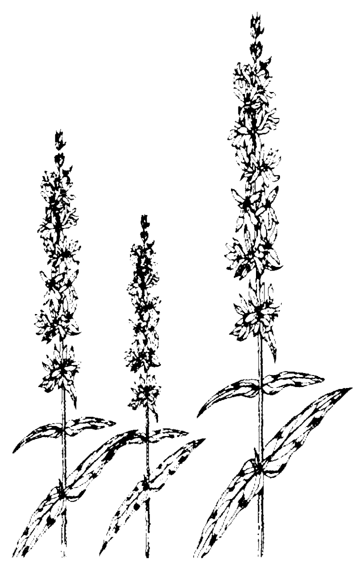
The Context of the Future: International Law and Global Change 10

Much of the debate about non-indigenous species (NIS) concerns the future-what trends related to the movement of species are inevitable and desirable. This debate takes place in the context of increasing ‘‘globalization’ of national economies and environmental problems. In the face of these changes, many consider unilateral regulation of the movement of MS inadequate, especially because international trade is among the most important pathways for harmful introductions. This chapter broadens our point of view by examining a few global socioeconomic and technological trends related to harmful MS and evaluating pertinent international law. Then, the chapter highlights specific predictions regarding the future status of MS, including scenarios related to species movement and global climate change.



INCREASING GLOBAL TRADE AND OTHER SOCIOECONOMIC TRENDS

Finding:

As international trade relationships change, new pathways for species exchange will open. Similarly, the increasing volume of international commerce in biological commodities—in part because of liberalized trade—is likely to increase the number of new species entering the United States.

Global social and economic trends have long affected the kinds, numbers, and pathways of MS that move around the world (ch. 3, table 3-5). Global population growth and economic expansion contribute to ever-greater demands on natural ecosystems, on agriculture, and on governmental institutions. Greater U.S. demand for particular kinds of foreign imports generates

Box 10-A-U.S. Exports of Non-indigenous Aquatic Species

The United States, as a trading partner and home base to many travelers, exports as well as imports harmful NIS. OTA has not systematically examined the United States' role as an exporter. However, some scientists and officials express concern that Federal and State authorities are not accountable for damaging species intentionally sent outside the United States.

A number of harmful or accidental U.S. exports have occurred. The slipper limpet (Crepidula fornicata) was inadvertently exported to Europe with a shipment of American oysters in the 1 880s; also Canadian scientists know or suspect U.S. origins for coho salmon *(Oncorhychus kisutch)* in Nova Scotia, an oyster disease in Prince Edward Island, and a trout disease from certified idaho trout. Bonamia ostreae, aparasiteof European oysters, probably originated in oysters shipped from California in the 1970s. R.L. Welcomme, of the Food and Agriculture Organization of the United Nations, lists 64 fish and other aquatic speciesthat were introduced to other countries from the United States for ornamental, sport fisheries, aquaculture, or other purposes. Not all established reproducing populations; nor have all been harmful. According to his records, the United States accounted for 240 of the 996 separate international introductions with known countries of origin.

Other kinds of species have also been exported. A North American moth is defoliating trees in large parts of central China. A pine wood nematode *(Bursaphelenchus lignicoius),* probably from the Southeastern United States, is killing black pines (Pinus *nigra)* in Japan. And ragweed *(Ambrosia* spp.) is spreading on the Russian steppes.

SOURCES: R.A. Elston, "Effective Applications of Aquaculture Disease-Control Regulations: Recommendations From an Industry Viewpoint" *Dispersal of Living Organisms into Aquatic Ecosystems, A* Rosenfield and R. Mann (ads.) (College Park, MD: Maryland Sea Grant, 1992), pp. 3S3-359; K. Langdon, Great Smoky Mountains National Park, U.S. Department of the Interior, Gatlinburg, TN, personal communication to K.E. Barmen, Office of Technology Assessment, Aug. 17, 199S; D.J. Scarratt and R.E. Drinnan, "Canadian Strategies for Risk Reductions in Introductions and Transfers of Marine and Anadromous Species," *Dispersal of Living Organisms info Aquatic Ecosystems,* A. Rosenfield and R. Mann (eds.) (College Park, MD: Maryland Sea Grant, 1992), pp. 377-385; R.L. Welcomme, *International Introductions of Inland Aquatic Species,* FAO Fishieries Technical Paper No. 294 (Rome: Food and Agriculture Organization of the United Nations, 19SS).

new and more heavily used pathways for accidental introductions. Foreign demand stimulates U.S. exports of species (box 10-A). Socioeconomic trends also drive the processes by which ecosystems become vulnerable to invasion. For instance, clearing land often eliminates indigenous vegetation and creates pathways for invaders; more recreational visitors to natural areas increases the likelihood that harmful NIS will invade them (105).

From the standpoint of harmful NIS, the continuing increase in global trade is among the most significant trends of the 1990s. Harmful NIS move via intentional commercial imports of live animals, live plants, seeds, and plant products, together with unintended ''hitchhikers" on these products or in the ships, planes, and trucks that transport them (ch. 3). The United States is a major market for these biologically based products, and imports of many are increasing. The opening of trade relationships through free trade agreements with Canada and Mexico and the General Agreement on Tariffs and Trade (GATT) will mean increased volumes of trade, as well as new trade routes. Climatic and ecological similarities between regions of the United States, Russia, China, and Chile, for example, suggest great potential for species exchange as trade increases.

The General Agreement on Tariffs and Trade

The United States recognizes the General Agreement on Tariffs and Trade (GATT)--the post-World War II agreement that liberalized global trade. GATT' set rules to eliminate national practices that distort free global markets and provided mechanisms for dispute settlement. The parties to this Agreement have been renegotiating since 1986 (the ‘‘Uruguay round’ ‘), with no final resolution yet.

GATT declares trade restraints invalid if they do not protect legitimate domestic interests. Article XX(b) acknowledges the need for parties to protect themselves from harmful NIS in that it legitimizes trade restraints, such as quarantine regulations, that are ‘‘necessary to protect human, animal, or plant life or health. ” However, some quarantines are alleged to be protectionist barriers designed to spare domestic products from foreign competition.

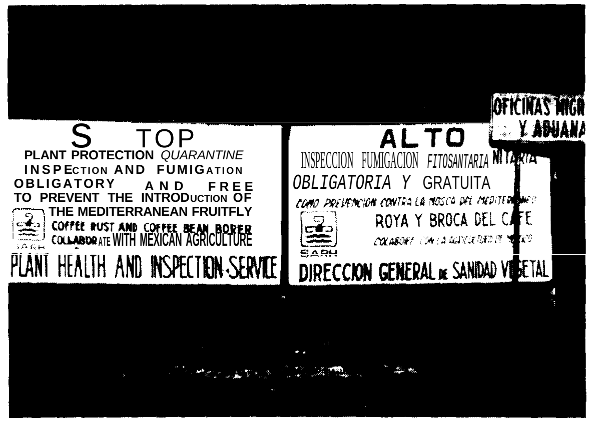
Pacific Northwest apple growers contend that Japan’s quarantine of their apples is an example, They claim to be shut out of the lucrative Japanese markets by a quarantine against the lesser apple worm *(Enorminia prunivora) (1),* a pest that is indigenous to the eastern United States. The insect exists in very low numbers in Northwest orchards; no outbreaks of quarantine significance have occurred since the 1950s. According to a Washington State University agricultural economist, the Japanese quarantine is scientifically ‘‘indefensible’ (71). Meanwhile, high-quality apples sell in Japan’s markets for the equivalent of $7 or $8 each.

Allegations have been raised by other countries about protectionist U.S. pest regulations as well. These include:

- restrictions on imports of cut flowers and potted plants from the Netherlands (2);
- a ban on seed potatoes from some Canadian provinces (4); and
- a ban on imports of Mexican avocados (81),

GATT has rarely been invoked to resolve these sorts of allegations.

Also, GATT authorities have only resolved a few disputes about whether environmental measures violate its norms of liberal trade (98). Under GATT, trade restraints are not to be imposed by



ANIMAL AND PLANT HEALTH INSPECTION SERVICE

Increased trade is likely to distribute more harmful non-indigenous species among nations but these changes have received scant attention in free trade agreements--like that proposed with Canada and Mexico.

one party to compel another to change its environmental practices. In 1992, a GATT dispute settlement panel decided that provisions of the U.S. Marine Mammal Protection Act [1] amounted to an unfair trade restraint (98). These provisions banned imports of Mexican tuna caught using methods that kill dolphins (34). Under GATT, the United States may impose bans on such imports only if their very presence is harmful, that is, if the imports could introduce pests. However, GATT does not allow quarantines if they discriminate against foreign imports without scientific justification.

Little systematic analysis of the environmental impacts of different trade patterns or policies has been done (98). Some groups have proposed that U.S. acceptance of future changes to GATT or other trade agreements be subject to formal environmental review. The applicability of the National Environmental Policy Act (NEPA)[2]— the law that requires environmental impact as-

[1] Marine Mammal protection Act of 1972, as amended (16 U. S.C.A. 1361 *et seq.*)

[2] National Environmental Policy Act of 1969 (42 U. S.C.A. 4321 *et seq.*)

sessments for Federal actions—to trade agreements is not resolved legally.[3]

GATT's solution to unfairly restrictive quarantine standards is to encourage parties to ''harmonize" their standard-setting criteria. All parties need not regulate the same pests. However, they should recognize common principles, adopt equivalent definitions of key terms like "economic pest, ' and use comparable criteria for deciding whether to quarantine imports (69). This would make quarantine decisions more amenable to objective scrutiny.

Harmonization does not in and of itself lead to more liberal importation. It could, however, reduce the cases of protectionism disguised as quarantine standards. Reaching agreements on acceptable levels of pest risk presents great difficulty in practice. The proposed harmonized risk analysis prepared for the Food and Agriculture Organization of the United Nations (FAO) concedes this: ''it is not possible to define a level of risk that is acceptable for all situations" (69). Currently, determnining acceptable levels of risk is a sovereign decision made by individual governments (11). In addition, pest risk analysis often entails high uncertainty (ch. 4). Given these obstacles to achieving international consensus, complete harmonization of pest risk standards is probably not achievable, although agreeing on analytical processes may be.

Greater international harmonization raises two main concerns. First, many developing countries lack the resources or expertise for the sophisticated risk analyses that are feasible for developed countries (63). Second, an overriding GATT approach could preempt national, State, and local MS laws (84,107).

The concern is whether the United States would be obligated to strike down or preempt a State law that requires a more rigorous pest risk analysis for imports than the international ' 'harmonized' approach under GATT. GATT's current draft language would support the State's case, as long as its laws use ''science-based' risk analysis (108). A State might, however, ban a class of imports on the grounds that uncertainty prevented determining which should be allowed and which prohibited. At the same time, State officials might be unwilling or unable to undertake the research necessary to remove those uncertainties. Then the foreign exporter could argue that the State's ban was not based on scientific evidence and therefore violated GATT.[4] GATT's current emphasis on harmonization generally-including pesticide and food safety standards-has been criticized by some legislators and environmental groups as sacrificing national, State, and local environmental controls for the ideal of global free trade (78,98).

Free Trade Agreements With Canada and Mexico

Canada and Mexico are the top two suppliers of U.S. agricultural imports (100). Considerable effort has been expended to coordinate pest prevention approaches with both. The pest-related provisions of the existing Canada-U.S. Trade Agreement (signed in 1988) constitutes a continuation of these efforts (101). The proposed North American Free Trade Agreement (NAFTA), which would create a Canada-U.S.-Mexico free trade bloc, includes language on harmonization of pest risk approaches similar to that in the current GATT draft (108).

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[3] On Sept. 15, 1992, a lawsuit was filed in the U.S. District Court for the District of Columbia challenging the Government's lack of environmental analysis under NEPA for the proposed North American Free Trade Agreement. *Public Citizen, et al., v. Office of the United States Trade Representative, et al.*, Cause No. 92-2102. On June 30, 1993, the court ruled that NEPA applied. However, the United States filed an appeal on July 2, 1993, in the Court of Appeals for the District of Columbia, *Public Citizen et al., v. Espy et al.,* Cause No. 93-5212, The appeal has yet to be decided.

[4] The issue of preemption of U.S. national, State, and local NIS laws under GATT and the North American Free Trade Agreement is analogous to constitutional preemption of State and local laws by Federal laws (see ch. 7) and their potential unconstitutionality under the Interstate Commerce Clause (see box 7-A on the key U.S. Supreme Court decision, *Maine v. Taylor*).

NAFTA will increase the prospects of importing new non-indigenous pests by increasing the volume of agricultural and horticultural imports from Mexico (52). Programs to prevent pest exports traditionally have been weaker in Mexico, although the country recently strengthened its approach and capabilities (3, 11). By one estimate, Mexican agricultural exports to the United States would increase by only a few percent (41). By another estimate, commercial truck traffic across the U.S.-Mexico border could expand more than four-fold (to 8 million crossings) from 1990 and the year 2000 (104).

Extensive controversy and information have been generated regarding the environmental impacts of NAFTA. Little of this information relates specifically to the consequences of harmful NIS, however.

I Other Socioeconomic Trends

Additional socioeconomic trends are likely to shift the movements and impacts of harmful NIS (table 10-1). International travel is also expected to increase and play a key role in the emergence of new threats to human health (54), some of which are carried by insects or other vectors that are not indigenous to the United States.

Both the biological control and aquiculture industries are poised to expand (9,19,25,51). Rates of introduction linked to both of these industries are likely to increase in the future.

Consumer demand exceeds the capacities of catch-fisheries. The proportion of aquatic organisms raised by aquiculture is expected to climb from 11 percent to 25 percent of the global harvest by the year 2000 (72). Likewise, sport fishing is projected to double by the year 2030 (72),

As the aquiculture industry expands—and as researchers, commodity distributors, and the general public also transport fish and shellfish—some fisheries experts expect that species movements are likely to diversify, with the increased risk of spreading pathogens (3 1). On the other hand, some observers envision that new introductions will come to be judged by more consistent standards and that aquiculture and non-indigenous fish will be managed "in a manner that preserves the biological integrity of native and desired naturalized fish communities" (42).

Growing interest in environmentally sound methods of pest control is spurring development of commercial biological control. Interest also is growing in applying biological control to new environments, for example, the use of blue crabs (Callinectes *sapidus)* to control zebra mussels *(Dreissena polymorpha) in* lakes and rivers (76). Biological control brings the risk of new species introductions and unexpected effects. Biological control agents, like other introductions, also can carry associated pests unintentionally, although quarantines are in place to prevent this.

Gardening is already the most popular leisure activity in the United States—involving 1 in 3 adults—and most surveys predict that gardening will grow. Nursery stock, seeds, equipment and so on amount to a $9 billion industry (109). Gardeners, in their search for plants that are novel, that reflect particular cultures, or that reflect fashion trends, are spurring changes in the seed and plant industry (40). For example, demand for wildflower seed is so keen that supplies do not meet demand, and some seeds are imported from Europe (40). Drought- and heat-tolerant species are especially popular. Gardening trends could have a variety of implications for NIS. Wildflower seeds are a largely unregulated potential source for the unintentional import and interstate movement of harmful NIS (ch. 1). Gardeners' demands could spur removal of technical and marketing bottlenecks to the use of indigenous species and thus decrease demand for potentially risky NIS imports.

Predicting changes in species use is an uncertain proposition. Even the more exhaustive studies tend not to evaluate species use at this level of detail. For example, agricultural economist Pierre Crosson's (22) future scenarios for U.S. agriculture focuses broadly on production of wheat, major grains, and soybeans. Other recent analyses

Table 10-1—How Social and Economic Factors and Technological Innovations Could Change the Status of Non-Indigenous Species in the Future

Social and Economic Factors	
Factors	**Potential effects**
Seed exchanges between previously isolated regions, e.g., Russia and the United States	Could increase international spread of pests and pathogens
Increased cross-border movement of material and refugees due to regional wars	Could break down national inspection and quarantine systems and increase the spread of NIS regionally
Doubling of U.S. air passengers by the year 2000	Could increase interstate spread of harmful species
Broadened interest in ornamental uses of indigenous plants	Could decrease incentives for foreign plant exploration and importation; could spread non-indigenous plants of U.S. origin throughout the country
Increased interest in smaller pets for urban areas	Could increase demand for non-indigenous fish and birds
Increased interest in planting forage for wildlife	Could increase introduction of non-indigenous plants to natural areas
Increased concerns regarding risks of chemical pesticide use	Could result in loss of some effective techniques to exclude, manage, or eradicate NIS
Increased interest in protecting endangered species	Could lead to relocations of species and additional introductions

Possible Technological Innovations	
Innovations	**Potential effects**
Further development of biological control for NIS	Could increase imports of control agents
Improvements in pest eradication mentods	Could cut needs for widespread pesticide spraying in urban areas
Improvements in detection equipment at ports of entry, e.g., molecular probes and biomarkers	Could increase interception of contaminated seed lots, microbes, and other small NIS
Upgraded ballast water exchange systems	Could reduce likelihood of unintentional introductions of aquatic NIS
Progress in genetic engineering	Could blur distinctions between indigenous and NIS astraits are traded
Domestication of “microlivestock” such as the black iguana *(Ctenosaura* spp.) and giant rat *(Cricentmys gambianus, C. emini).*	Could create new pathways for introductions and could spread vertebrate diseases
Development of new plant species to replace shrinking traditional supplies of wood	Could cut imports of raw timber and associated pests
Use of “constructed wetlands” for wastewater treatment	Could increase direct planting of otherwise harmful NIS, such as the water hyacinth *(Eichhornia crassipes)*
Environmental remediation using bacteria, algae, and fungi	Could increase release of non-indigenous microbes

SOURCES: Anonymous, “Wildlife Market On the Rise,” Seed *World*, November 1991, p. 26; M.J. Bean, “The Role of the U.S. Department of the Interior in Nonindigenous Spedes Issues,” contractor report prepared for the Office of Technology Assessment, November 1991; G. Bria, “Newsletter Seeks Seed Swaps with Russians,” *The Washington Post*, Dec. 28, 1991, p. D3; A. Gibbons, “Small is Beautiful,” *Science*, vol. 253, No. 5018, Juiy 26, 1991, p. 378; L.A. Hart, Director, Human-Animal Program, University of California-Davis, cited in “Smaller Pets,” *The Futurist*, vol. 24, No. 2, March/April 1990, p. 5; R. Keeler, “Bioremediation: Healing the Environment Naturally,” *R & D Magazine*, July 1991, pp. 3440; D. Morris, “We Should Make Paper From Crops, Not Trees,” The Seattle *Times*, May 5, 1991, p. A12; National Research Council, *Microlivestock: Little-Known Small Animals With a Promising Economic Future*, Board on Science and Technology for International Development, N.D. Vietmeyer (cd.) (Washington, DC: National Academy Press, 1991); Partnership for Improved Air Travel, Washington, DC, dted in “Ailing Aviation Intrastructure Threatens U.S. Economy,” *The Futurist*, vol. 23, No. 6, November/December 1989, p. 7; S. Reed, “Constructed Wetlands for Wastewater Treatment,” *Biocycle*, vol. 32, January 1991, pp. 44-49.

of the nursery, greenhouse, and turf grass industries; floriculture; and forestry do not distinguish between indigenous and non-indigenous species (10,46,92).

TECHNOLOGICAL CHANGES

Finding:

Technological changes and other means will continue to add non-indigenous organisms to the United States, sometimes by new pathways. At the same time, certain technological innovations, e.g., improved predictive models and more biologically sophisticated pesticides, are likely to provide more effective ways to detect, eradicate, and manage NIS.

Technology, like social, economic, and political changes, will continue to alter the movement, survival, and impacts of NIS (table 10-1). Indeed, experts predict that technical innovation will proceed at increasing rates (18,86) and provide new approaches to preventing and solving environmental problems (16,20). Based on past experience, breakthroughs in transportation, pest control, and information management are most likely to affect NIS directly.

More complex pest control methods seem virtually certain as biotechnology expands (chs. 5, 9). Phytotoxins—plant-damaging compounds produced biologically by microbes-may form the next generation of herbicides; combinations of other biological control methods, the use of modified cultivation practices, and lowered chemical herbicide use may also be increasingly common (91). A host of new methods might ultimately be available to manage NIS more effectively. One biologist predicts: ‘‘ [i]t probably will be possible to eliminate most exotic species in less than a decade after the initiation of a program’ with methods such as the release of sterile males; genetically engineered, host-restricted pathogens; repression of pests immune systems; manipulation of reproduction; and the use of sexual attractants (86). Not all of these are near-term possibilities, however. And insect pests

Flourishing air travel is likely to bring more harmful non-indigenous species to the United States and spur technological innovations in detection and baggage handling that will have additional impacts.

have proved to be difficult to eradicate, even with sophisticated technology (30), despite repeated predictions that better methods were on the way.

Biotechnology will also shape the way indigenous and non-indigenous germ plasm is used and combined (ch. 9). Conventional breeders and specialists in biotechnology are increasingly turning their attention to fish. Fish with new adaptations to specific environments can be expected, along with larger fish and the use of more complex reproductive technologies to isolate new strains from indigenous species (72). Technology now allows more fish and shellfish species to be manipulated to limit their post-release reproduction—technology unavailable even 10 years ago (31). Likewise, plant breeders expect novel additions of genes through biotechnology (29,37). Management of some non-indigenous weeds will change, for example, when genes for herbicide resistance are introduced into crops.

Improved methods to assess risk and make decisions are underway and likely to develop further (ch. 4) (14). Other improved means of gathering and managing information remain tantalizing, but remote, possibilities. For example, computerized systems might enable worldwide tracking of pests and other species. The National Aeronautic and Space Administration uses extremely sensitive biomarkers to detect and identify microbes that might contaminate space missions (68). These techniques might eventually be adaptable to detecting NIS at ports of entry, although they require complex and expensive laboratory methods now. Medical technology might have new applications, e.g., nuclear magnetic resonance imaging (MRI) might be used to identify and classify previously unknown species (86) but cost prohibits such uses currently.

High-speed trains are already in service in some parts of the world and high-speed magnetic levitation systems are under development-other examples of technological innovation. In the past, higher speed transportation has increased the survival of intentionally and unintentionally transported NIS (ch. 3). High-speed ground transportation could accentuate this trend. Ultimately, experts envision that high-speed ground transportation would interconnect with highways and air travel (93). Difficulties in restricting NIS of foreign origin could increase if international airports become hubs for multiple high-speed ground transportation systems that automatically transfer baggage.

The caliber of international restrictions on the movement of harmful or potentially damaging NIS is significant, given the increasingly global nature of the socioeconomic and technological trends cited here. Many damaging NIS already in the United States, such as zebra mussels, arrived circuitously, sometimes crossing several international borders. The United States has vast agricultural and other natural resources that are vulnerable to damaging NIS. Thus, this country would be a major beneficiary of an international system that is as effective as possible. In the next section, OTA examines how well international treaty obligations protect the United States and others from damaging MS.

TREATIES AND THE MOVEMENT OF HARMFUL NON-INDIGENOUS SPECIES

Finding:

Generally, the international regulation of NIS is weak. Except for plant protection, no multilateral treaty to which the United States is a party directly addresses the risks of NIS imports, although the new Convention on Biological Diversity includes a weak provision on NIS.

International environmental laws have multiplied in the last 20 years but they remain weak compared with national prerogatives, as the laws tend to lack enforceability (96). International legal obligations can be important, however, and they are becoming more comprehensive.[5] A number of treaties address harmful NIS directly, with specific provisions. Others deal with related environmental issues and indirectly affect NIS (box 10-B). Only the former are discussed in detail here.

Some experts have called for more effective international laws regarding NIS, particularly to regulate aquatic releases (13,1 1 1). Of the three directly relevant multilateral treaties, one has only vague provisions on NIS (the Convention on Biological Diversity) and another has not been ratified by enough countries to take effect (the Convention on the Law of the Sea).

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5 Additional international mechanisms also relate to NIS. For example, the United States is a member of the International Council for the Exploration of the Seas (ICES) and a signatory to its Code of Practice. The Code is not an international law or regulation but a protocol and, thus, is discussed inch. 4.

Box 10-B—Main International Treaties with Provisions Related to Non-Indigenous Species

Multilateral Treaties Directly Affecting NIS

- **International Plant Protection Convention, signed by the United States in 1972**
- **Convention on Biological Diversity, signed by the United States in 1993**
- **Convention on the Law of the Sea, United States has not signed**

Bilateral Treaties Directly Affecting NIS

- **Convention on Prevention** of Diseases in Livestock (U.S.-Mexico), signed in 1928
- Boundary Waters Treaty of 1909 (U.S.-Canada), in particular the Great Lakes Water Quality Agreement of 1978, as amended in *1987*
- Convention on Great Lakes Fisheries (U.S.-Canada), signed in 1954
- Convention Concerning the Conservation of Migratory Birds and their Environment (U.S.-U.S.S.R), signed in 1976

Multilateral and **Bilateral Treaties With Indirect Effects on NIS.**

These generally protect habitats or groups of indigenous species deemed to have major conservation significance.

- **Convention Concerning the Protection of the World Cultural and Natural Heritage, signed in 1973**
- **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), signed in 1975; (see box 10-C).**
- **Convention on Wetlands of International importance Especially as Waterfowl Habitat** signed in 1985
- Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere, signed in 1942
- Convention for Protection and Development of Marine Resources of the Wider Caribbean Region, signed in 1983
- Convention for the Protection of Migratory Birds (U.S.-Canada), signed in 1916
- Convention for the Protection of Migratory Birds and Game Mammals (U.S.-Mexico), signed in 1936

The bilateral migratory bird treaties focus on harvest restrictions and include general provisions to preserve important habitats. The United States would be obligated to protect such habitats if they were threatened by NIS. However, these older treaties tend to be less comprehensive and to lack adequate legal mechanisms to enforce obligations.

NOTE: Dates given are for U.S. signature. Agreements were established and opened for signature either in the same year or up to several years earlier. The Convention on Biological Diversity haa not yet been ratified by the Senate.

SOURCES: S. Lyster, *International Wildlife* Law(Cambridge, England: Grotius Publications, 19S5); U.S. Congress, Office of Technology Assessment, *Technologies* to *Maintain Biological* Diversify, OTA-F-330 (Washington, DC: U.S. Government Printing Office, March 1987).

The International Plant Protection Convention (IPPC)

IPPC covers agricultural pests. Created under United Nations auspices, this major multilateral treaty has been signed by 94 countries, including the United States in 1972. It establishes a framework for cooperation in agricultural pest regulation; lays out general and specific quarantine principles; standardizes terminology and permits; and provides a process for resolving disputes (47). It aims to:

- strengthen international efforts to prevent the introduction and spread of pests of plants and plant products,
- secure international cooperation to control pests and to promote measures for pest control, and
- ensure adoption by each country of the legislative, technical, and administrative measures to carry out the Convention's provisions (15).

IPPC requires each signatory to establish a plant protection organization to undertake certification, inspection, control, and research; to conduct surveys; and to share information. This does not guarantee uniform performance by all parties. Training, equipment, and facilities differ among the parties and are lacking altogether in some (15).

From the U.S. perspective, this unevenness means that agricultural agencies in many exporting countries cannot be relied on to keep potentially harmful pests out of shipments. In some cases, it has been advantageous to assist developing countries in improving their pest prevention infrastructures, as with economically important Mexico.

The Food and Agriculture Organization of the United Nations (FAO) administers IPPC with input from regional plant protection organizations, such as the North American Plant Protection Organization, to which the United States belongs. Proposals for changes to IPPC include: the need for its own secretariat, separate from and stronger than the current FAO administration (48); and expanded coverage beyond commercial plants, that is, to explicitly protect indigenous plants in non-agricultural areas (12).

No convention comparable to IPPC exists for animals or their pests, but livestock disease prevention terminology and information is coordinated by the International Office on Epizootics. Based in France, it is the international standard setting organization for animal health.

The Convention on Biological Diversity

Plans for a global multilateral convention on international protection of biological diversity have been discussed since 1982 (53). At the request of the U.N. Environment Programme, the International Union for the Conservation of Nature and Natural Resources's (IUCN) Environmental Law Centre prepared the initial draft (44). The goal was to present a convention at the U.N. Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil, in June 1992.

Initially, a detailed "alien species" article would have obligated the parties to: prevent introductions harmful to biological diversity; attempt eradication of existing harmful introductions; and be attentive to the determinations of a new international expert body (to be created by the Convention) as to harmful species, risk management, and eradication. Several preparatory meetings for UNCED considered the alien species article and weakened the IUCN draft, reducing the specificity of the obligations and eliminating the proposed expert body. In the version of the "Convention on Biological Diversity" presented at Rio de Janeiro, and signed by almost all counties except the United States, the alien species provision reads:

> Each Contracting Party shall, as far as possible and appropriate: . . . (h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species (95).

The initial obstacles to U.S. signature were financial and legal concerns concerning biotechnology; language regarding property rights; and inadequate provisions for financial oversight by donors (103). The alien species provision did not contribute to the U.S. refusal. The United States later signed the Convention in June 1993 but the Senate has not yet acted on ratification.

The Convention on Biological Diversity does not hold much promise for significantly reducing unwanted international exchanges. The alien species provision is vague and probably unenforceable. This approach contrasts significantly with the detailed requirements of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), an important and relatively successful treaty (57). Paul Munton, who chairs the Introductions Specialist Group for IUCN's Species Survival Commission, suggested that CITES could serve as a model for international regulation of harmful non-agricultural NIS, i.e., those not covered by IPPC (67). However, CITES has both strengths and weaknesses as a model (box 10-C). U.N. officials, other international experts, and the U.S. International Trade Commission have suggested recently that monitoring compliance with CITES and other international agreements needs more attention (96). Suggested improvements include monitoring efforts like those used by GATT, the International Labor Organization, or other groups.[6]

The Convention on the Law of the Sea

The United States has not signed the sole multilateral convention with provisions specific to marine introductions, the Convention on the Law of the Sea. Indeed, the Convention has not taken effect because fewer than the required number of countries have ratified it. The United States refused to sign the Convention primarily because of concerns over distribution of revenues from deep sea-bed mining (53). However, the Reagan administration did express its intent to voluntarily comply with the non-mining provisions (102).

The Convention proposes an international approach to marine introductions:

> States shall take all measures necessary to prevent, reduce, and control pollution of the marine environment resulting from the use of technologies under their jurisdiction or control, or the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto (Article 196) (94).

Articles 197 and 200 call for formulation of standards on a cooperative global or regional basis to prevent harmful introductions and to conduct coordinated research on ''pathways, risks, and remedies. '

Bilateral Treaties

The United States has adopted several bilateral agreements on agricultural quarantines and animal health with Canada and Mexico. These are agreements between corresponding agency departments, without treaty status. The United States and Mexico did sign a convention to protect livestock in 1928 that has facilitated mutually advantageous veterinary programs, such as U.S. participation in the control of foot and mouth disease in Mexico in the 1940s and 1950s (66).

The Boundary Waters Treaty of 1909 covers the Great Lakes. The International Joint Commission co-manages the treaty and has overseen agreements on NIS such as the zebra mussel (39). The invasion of the sea lamprey (Petromyzon *marinus) in the early 1900s,* which devastated indigenous fish populations, precipitated the establishment of another treaty in 1955—the Convention on Great Lakes Fisheries (33). The Great Lakes Fishery Commission administers this treaty and coordinates sea lamprey control. Also, the Commission coordinates fish stocking with such NIS as Pacific salmon (Oncorhynchus spp.). Disputes among the parties (States, Provinces, and Federal Governments) regarding fish restoration were anticipated by the Joint Strategic Plan adopted in 1980 (38). The Plan calls for consensus before unilateral actions, and the Commission can arbitrate if a dispute cannot be resolved otherwise.

Outside the Great Lakes, disputes have occurred between individual States and the Canadian and Provincial governments over fish releases. North Dakota's experimental release of the European zander (Stizostedion lucioperca) raised concerns not only because of uncertainty over impacts from the fish itself, but also from two potentially associated non-indigenous fish diseases (5). No direct legal mechanism like the

[6] In January 1991, Senator Daniel Moynihan introduced Senate bill S .59, the General Agreement on Tariffs and Trade for the Environment Act of 1991. This bill proposed using GATT to monitor and enforce international environmental agreements (96).

Box 10-C-CITES as a Model for International Regulation of Non-Indigenous Species

The Convention on International Trade in Endangered Species of Wild Fauna and flora (CITES) is credited with saving many species from extinction and has been called the most successful international treaty concerned with wildlife conservation. It has had its share of difficulties, too—many involving political disagreements. CITES regulates and monitors international wildlife trade, business that grosses between $5 billion and $17 billion annually.

CITES detailed approach is quite different from that of the Convention on Biological Diversity and thus represents an alternate model for regulating those harmful NIS not already covered by the International Plant Protection Convention or other agreements. However, CITESisintended to prevent harm inthe exporting country. The major threat from trade in NIS is harm in the importing country. (Trade in some species, though, may cause harm for both parties. For example, exporting rare parrots can diminish South American fauna and threaten indigenous U.S. birds with disease if they escape here. Tree ferns are rare and protected in Australia, but they are invasive (e.g., Cyathea cooperi) when imported in Hawaii.) Also, CITES regulates only intentional movements; unintentional movements are important pathways for harmful NIS.

Positive features of CITES that are potentially applicable to trade in NIS are:

- regularly updated lists of hundreds of species for which trade is prohibited and over 27,000 species for which trade is monitored by a permit system;
- an independent secretariat, with staff and budget;
- a trust fund to finance the secretariat and biennial meetings of the parties;
- a network of national Management Authorities to address the mechanics of trade, and Scientific Authorities to address biological aspects, in most signatory countries; these commicate directly with each other and the secretariat;
- international forums for governments and non-governmental groups;
- technical advice from various expert organizations, including the IUCN's Wildlife Trade Specialist Group; and
- facilitation of enforcement against CITES violators (including non-parties) via trade sanctions adopted by the parties.

(continued)

Great Lakes agreement, existed for Canada to challenge the action by North Dakota.

In sum, international agreements that control the movement of harmful NIS are quite limited. What kind of future can be predicted, given the continuing, and probably increasing, numbers and kinds of NIS in international transit?

FROM TRENDS TO PREDICTIONS

Finding:

Many experts anticipate increasingly negative impacts from unintentional introductions of NIS in the long term. OTA concurs that there is considerable cause for concern. At the same time, future problems associated with intentional importations and releases could be reduced if appropriate screening and regulatory programs are adopted and implemented.

A Pessimistic View of the Future

Many researchers are strikingly pessimistic about slowing and managing harmful introductions. Some anticipate:

> a future ". , . with invasion sure to play an increasingly important role in the ecology of the biosphere . . ." (106)
>
> ''continued mixing of the regions' biotas . . ." (36)
>
> an ". . . inexorable invasion of all biotas by alien species from other regions, biomes and continents." (87)

Negative features of CITES that detract from it as a model for international regulation of NIS are:

- **a narrow** focus on trade, which excludes non-commercial pathways;
- the tendency, by restricting all trade in a given species, to penalize the countries that manage species carefully along with those that manage carelessly;
- creation of a harmful underground trade (approximately one-fourth to one-third of threatened and endangered species trade is estimated to be illegal);
- lack of scientific knowledge and/or political will in many countries to make appropriate listings and to enforce permits;
- the opportunity for countries that disagree with CITES on particular listings to exempt themselves by entering "reservations;"
- limited compliance with reporting requirements and **lack** of enforcement measures specified in the treaty itself; and
- lack of uniform documentation for importing and exportingcountries, making misrepresentation and forgery easier;

For the United States, in particular, CITES' weaknesses include: insufficient importation inspection capability, lack of information on enforcement, excessive allowance of imports through non-designated ports, and inadequate assessment and collection of penalties.

SOURCES: C. Beasley, Jr., "Live and Let Die," *Buzzworm*, vol. 4, July-August 1991, p. 2S-SS; F. Campbell, Natural Resources Defense Council, Washington, DC, personal communication to the Office of Technology Assessment, Dec. 24, 1992; G. Hemley, "international Wildlife Trade," Audubon *Wildlife Report* 198S/19S9 (San Diego, CA: Academic Press, 19SS); S. Lyster, *International Wildlife* Law (Cambridge, England: Grotius Publications, 1SSS); J.A. McNeely et al., Conserving *the World's Biological Diversity* (Gland, Switzerland: IUCN et al., 1990); P. Munton, "Problems Associated With Introduced Species," paper presented at the Workshop on Feral Animals at the Third International Theriological Conference, Helsinki, Finland, August 1982; U.S. Congress, General Accounting Office, *International Environment: International Agreements are Not Well Monitored*, GAO/RCED-92-32 (Gaithersburg, MD: U.S. General Accounting Office, January, 1992); Worldwatch Institute, State *of the World -1992 (New York, NY:* W.W. Norton Co., 1992).

"In the face of ongoing habitat alteration and fragmentation, this implies a biota increasingly enriched in wide-spread, weedy species-rats, ragweed and cockroaches . . . .' (45)

" . . . that the circumstances conducive to the invasion of introduced species will become more widespread in the future, not less widespread. " (59)

"Because of increasing contact and exchange throughout the world, introductions of exotic pests will take place with increasing frequency . . . " (23).

" . . . as species are introduced or move in response to environmental changes, some of today's desirable species may become pests in their new environmental context, while some pests may become more pernicious. " (56)

' 'If we look far enough ahead, the eventual state of the biological world will become not more complex but simpler—and poorer. Instead of six continental realms of life with all their minor components of mountain tops, islands and fresh waters, separated by barriers to dispersal, there will be only one world, with the remaining wild species dispersed up to the limits set by their genetic characteristics, not to the narrower limits set by mechanical barriers as well. " (32)

When people speculate about the future, they tend to be predominantly pessimists or optimists; the work of futurists has even been categorized on that basis (62). Whether these experts are unduly pessimistic or not, they picture a serious problem that is getting worse. One prominent conservation biologist sees the spread of NIS as the only high impact threat to biological diversity that affects both richer and poorer countries at every level of biological organization-from single genes to whole landscapes (88). In order to supplement these views, OTA asked its Advisory Panel to envision the world's future regarding NIS also.

Box 10-D-OTA's Advisory Panel Envisions the Future

OTA's Advisory Panelists (p. iv) have been dealing with NIS for much of their professional lives and are more expert than most in assessing what the future might hold. Fallowing are some of the fears and hopes they identified when asked to ponder the best and worst that might be ahead.

Life Out of Bounds . . .

"The future will bring more reaction to zebra mussels (Dreissena polymorpha) and inaction to the massive alteration of natural habitats and natural flora and fauna . . . By the mid-21st Century, biological invasions become one of the most prominent ecological issues on Earth . . . A few small isolated ecosystems have escaped the hand of [humans] and in turn NIS. . . One place looks like the next and no one cares . . . The homogeneity may not be aesthetically or practically displeasing, but inherently it diminishes the capacity of the biotic world to respond to changing environments such as those imposed by global warming . . . The Australian melaleuca tree (Melaleuca quinquenervia) continues its invasive spread and increases from occupying half a million acres in the late 1980s to more than 90 percent of the Everglades conservation areas."

. . . Or Life **In Balance**

"An appropriate respect for preserving indigenous species becomes **a** national goal by consensus . . . All unwanted invasions are treated with species-specific chemicals or by vast releases of 100 percent sterile triploids (created quickly) that depress the exotic populations. Invasions slow to a trickle and fade away like smallpox . . . Jobs for invasion biologists fade away . . . [There is] an effective communication network, an accessible knowledge base, a planned system of review of introductions, and an interactive, informed publlc . . . Native [species] are still there in protected reserves . . . The contribution of well-mannered NIS-for abuse-tolerant urban landscaping, for ornamental in gardens, for biological control of pests, for added interest, for increased biodiversity, for new food and medicine-is appreciated. The overarching criterion for judging the value of a species is its contribution to the health of its host ecosystem."

SOURCE: Advisory Panel Meeting, Office of Technology Assessment, July 29-30,1992, Washington, DC.

Their worst case scenarios are similar to those excerpted above (box 10-D).

Such scenarios would have substantial financial, as well as environmental, costs. The worst case scenarios of future U.S. economic losses from 15 harmful NIS could total $134 billion[7] (table 10-2). These figures are based on available economic projections, ranging from 1 to 50 years. However, far more than these 15 harmful NIS are likely to create losses in the future (ch. 2, 3). For example, if leafy spurge *(Euphorbia esula)* is allowed to spread unrestricted throughout Montana, South Dakota, and Wyoming, annual impacts could reach $46 million by 1995 (6). Similar cost estimates are not available for most harmful MS, however. Nor do these projections account for analogs to the zebra mussel—those surprise species that radically and rapidly alter economic outlooks.

Island species, as well as those inhabiting long-isolated bodies of freshwater, will remain at high environmental risk from non-indigenous predators, diseases, and competitors from continental regions (ch. 8) (86). Generally, however, island-like continental areas (such as isolated mountains) have not experienced the same degree of evolutionary isolation and thus are less likely to be as vulnerable to MS-caused extinctions as oceanic islands are (59).

In the future, larger proportions of harmful introductions will be unplanned as controls are likely to tighten on intentional ones. Most ani-

[7] Past economic losses are provided in ch. 3.

Table 10-2—Worst Case Scenarios: Potential Economic Losses From 15 Selected Non-Indigenous Species[a]

Group	Species studied	Cumulative loss estimates (in millions, $1991)[b]
Plants	melaleuca, purple loosestrife, witchweed	4,588
Insects	African honey bee, Asian gypsy moth, boll weevil, Mediterranean fruit fly, nun moth, spruce bark beetles	73,739
Aquatic invertebrates	zebra mussel	3,372
Plant pathogens	annosus root disease, larch canker, soybean rust fungus	26,924
Other	foot and mouth disease, pine wood nematodes	25,617
Total	15 species	134,240

a See index for scientific names.

b Estimates are net present values of economic loss projections obtained from various studies and reports on selected potentially harmful NIS. Many of the economic projections are not weighted by the probability that the invasions would actually occur. Thus, the figures represent worst case scenarios. The periods of the projections range from 1 to 50 years.

SOURCE: M. Cochran, "Non-Indigenous Species in the United States: Economic Consequences," contractor report prepared for the Office of Technology Assessment, March 1992.

mals are intentionally imported and released and heightened awareness should limit further releases of harmful entries (59) (box 3-b).

Some observers expect that weed problems are likely to become greater and more complex (35,59). The significance of woody weeds is likely to increase in Mediterranean-like regions of the world, including California, while better management may cause other types to decline (36). Many U.S. weeds have close relatives overseas. As more of these weeds reach the United States, hybridization could sufficiently alter the non-indigenous weeds to make identification of their natural enemies difficult; as a result, biological control would progress more slowly (30),

Likewise, some forests may experience more severe insect and disease outbreaks as new pests add to the cumulative damage of current ones (7). One prominent conservation biologist expects control of various NIS to be a growth industry and anticipates calls for massive spraying of pesticides (87).

The Next Pests

OTA identified 205 foreign species that were introduced or detected in the United States between 1980 and 1993; 59 are known to be harmful (table 3-l). For those that become established, impacts are likely to increase as their ranges expand. This kind of data could alert managers to new and potentially damaging NIS. However, such information is scattered and of highly variable quality.

USDA's APHIS tracks certain overseas pests and diseases. This is a daunting task. Thousands of organisms are potential pests, but a smaller number are most likely to reach the United States and become established. The USDA Veterinary Service identified 61 diseases of livestock and poultry and 4 fish diseases of particular concern; veterinarians receive these reports and are asked to look out for new diseases (52). The most recent, comprehensive assessment of future plant pests for the United States identified 1,200 species still restricted to other countries (75). Plants worth watching include:

- 23 species plus 8 multispecies genera of aquatic, parasitic, or terrestrial plants prohibited from entry by the Federal Noxious Weed Act (FNWA); and
- 29 species, 10 genera, plus 6 families of weedy plants that are not listed on the FNWA (60).

Preventing damage by the first group depends on the effectiveness of the system back stopping the Federal Noxious Weed Act. The second group of plants also poses significant economic and ecological hazards, but the FNWA provides no protection from them. Many species in this group have close relatives in the United States that are already troublesome weeds (60). Another 29 species and one genus of non-indigenous weedy plants are present in the United States but not yet widespread. Examples of the most significant of these 3 categories of potential U.S. weeds appear in table 10-3.

Neither the Federal Government nor most State Governments make systematic efforts to evaluate such imminent problems. Within USDA, support has been sporadic for the databases that would provide early warnings (ch. 5). On the other hand, Minnesota recently completed an assessment of threats from MS; 11 plant, 8 insect, 5 fish, 2 invertebrate, and 7 vertebrate species were identified as potential pests not known to occur in Minnesota as of January 1991 (65). Also, the Federal interagency Aquatic Nuisance Species Task Force is developing an information system on non-indigenous aquatic species and their effects. This part of the Task Force's proposed Aquatic Nuisance Species Program is intended to provide timely notification of the detection and dispersal of these organisms.

Climate Change: the Wild Card in Predictions

Finding:

Projected ecological disruption from climate change would increase the probability of invasions by NIS. Also, it would inject great complexity into defining what is and is not indigenous and cause even more policy-making difficulty than currently exists. In particular, new policies would be needed to address whether movements by populations in response to climate change should be treated passively—as if they were natural-or actively.

Scientists are confident that human activity is dramatically changing the chemical makeup of the Earth's atmosphere (97). Atmospheric concentrations of the greenhouse gases that trap heat in the atmosphere-carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons-have increased rapidly over the last 100 years, generally as a result of human activity. The Intergovernmental Panel on Climate Change concluded that the global mean temperature could increase from today's level by roughly 2.2 °F (1.0 'C) by 2030 and 6.6 °F (3.0 'C) by 2100 if present emission levels continue (43). Because greenhouse gases may persist in the atmosphere for up to a century, some amount of global warming appears unavoidable even if countries take stringent measures to limit further emissions today (43).

Temperature changes of this magnitude would have significant effects on the distribution of indigenous and non-indigenous species. Any predictions about the future status of harmful NIS need to account for the possibility of global climate change.

Many uncertainties surround predictions of climate change. However, 100-year increases of 1.5 to 5.5 °C fall in the middle range of most models' predictions. If realized, these levels would make the Earth warmer than at any time in the past 200,000 years (1 10), with temperatures rising at a rate perhaps 15 to 40 times as fast as past natural changes (80).

Living organisms are quite sensitive to temperature and temperature-related parameters such as precipitation, humidity, and soil moisture. To find the same temperature, a 3 °C increase requires a northward shift of 250 kilometers or an upward elevational movement of 500 meters (58). Different species will shift ranges at different rates. Estimates for individual species project larger range shifts: 350 km northward for loblolly pine *(Pinus taeda)* (64) and 500 to 1,000 km for 4 common North American trees[8] (24). Such species relocation may be possible for highly mobile organisms or for those that readily colonize new

[8] Beech (*Fagus grandifolia*), yellow birch (*Betula alleghaniensis*), eastern hemlock (*Tsuga canadensis*), and sugar maple (*Acer saccharum*).

Table 10-3—Examples of Weedy Plants With Potential for Significant Economic or Ecological Harm

Common (when available) and scientific names	Comments
Weedy plants not established in the United States and prohibited from entry by the Federal Noxious Weed Act (FNWA)	
Monochoria vaginalis	aquatic weed of rice fields throughout Asia
African payal *(Salvinia auriculata)*	South American aquatic weed now troublesome in Africa; closely related to one of world's worst weeds (S. *mdesta)*
Dodders *(Cuscuta* spp.)	parasitic plant of many crops; worldwide problem (some species in warmer parts of United States)
Broomrapes *(Orobanche* spp.)	parasitic plant of many crops; worldwide problem
Witchweeds *(Striga* spp.)	parasite mostly of grasses; widespread in India, Africa
Couchgrasses *(Digitaria* spp.)	terrestrial weed of fields, disturbed areas in Africa
African boxthorn *(Lycinum ferocissimum)*	terrestrial hedge plant--escaping; serious weed of natural areas and fields in South Africa, Australia New Zealand
Serrated tussock *(Nassella trichotoma)*	terrestrial weed of fields, waste places; one of worst weeds in New Zealand
Weedy plants not established in the United States and not listed by the FNWA	
Tutsan *(Hypericum androsaemum)*	*close* relative to already troublesome U.S. weed; found in roadsides, damp places in Europe, North Africa, Australia
(Oxylobium parviflorum)	one of worst poisonous plants; found in western Australia
Bromegrasses (Bromus spp.)	close relatives to already troublesome U.S. weed; weeds of arid sites in central Asia, Russia, Mediterranean region
(Avena strigosa)	*close* relative to already troublesome U.S. weed; weed in corn and oats fields in central Europe and Mediterranean region
Panic grasses *(Panicum* spp.)	climbs over vegetation; problem in tropical Africa and Asia
Sedges (Cyperaceae)	weeds of waste places, cultivated fields, and wet areas near ponds, streams, rivers; worldwide; multiple genera
Weedy plants in the United States but not yet widespread	
Common crupina *(Crupina vulgaris)*	listed under FNWA; problem along roadsides and in waste places in Idaho; eradicated in California
Catclaw mimosa *(Mimosa pigra* var. *pigra)*	listed under FNWA; wide-spread in tropical Africa; quarantined in Australia; present in Florida
Persian darnel *(Lolium persicum)*	not listed under FNWA; weed of fields and waste places in North Dakota
Cudweed *(Filago arvensis)*	not listed under FNWA; weed of fields, waste places, overgrazed rangeland in Washington and Oregon
Tall fescue *(Festuca arundinacea)*	not listed under FNWA; poisonous to livestock; found in roadsides, gullies, canals in Florida and the Pacific Northwest
(Thladiantha dubia)	not listed under FNWA; vine that climbs over vegetation; found in New Hampshire and Minnesota
Raoul grass *(Rottboellia exaltata)*	listed under FNWA; invading sugarcane fields in Florida and Louisiana
(Medicago polymorpha)	not listed under FNWA; weed of cultivated areas and waste places; found in Hawaii and almost worldwide

SOURCES: R.N. Mack, "Additional Information on Non-Indigenous Plants in the United States," contractor report prepared for the Office of Technology Assessment, October 1992. Compiled from: R.D. Blackburn, L.W. Weldon, R.R. Yeo, and T.M. Taylor, "Identification and Distribution of Certain Similar-Appearing Submersed Aquatic Weeds in Florida," *Hyacinth Control Journal*, vol. 8, 1969, pp. 17-21; R.A. Creager, "Seed Germination, Physical and Chemical Control of Catclaw Mimosa (*Mimosa pigra* var. *pigra*), *Weed Technology*, *vol. 6, 1992,* pp. 864-891; T. Miller and D. 20Thill, "Today's Wead: Common Crupine (*Crupina vulgaris*), *Weeds* Today, vol. 14, *1983,* pp. 10-1 1; C.F. Reed and R.O. Hughes, *Economically Important Foreign Weeds,* Agriculture Handbook Number 498 (Washington, DC: U.S. Department of Agriculture, 1977); R.G. Westbrooks, "Introduction of Foreign Noxious Plants into the United States," *Weeds* TO&Y, vol. 12, 1981, pp. 16-17.

areas. Some evidence indicates that northward range shifts are already happening (79).

Species that cannot relocate fast enough may be able to adapt genetically to climate changes. However, most species' physiological adaptations to climate are highly conservative. They are unlikely to evolve fast enough to fit such rapidly changing conditions and extinctions of populations and species can be expected (74).

Also, biological, geographic, or human-caused factors such as habitat destruction may prevent many species from adjusting their ranges or otherwise responding successfully. Even those species capable of spreading rapidly to cooler sites may not flourish given new soil conditions, changes in day length, or different food sources and they may also be extirpated (74). Indeed, the most successful species are likely to be those adept at invading new habitats, including many current pests and pathogens (26).

New species may arrive from overseas or spread north from Mexico, the Caribbean, or from the southern United States. For example, models predict that at least a few agricultural pests and pathogens, such as the potato leafhopper *(Empoasca fabae),* which feeds on soybeans and other crops, are likely to experience expanded areas in which they can survive winter temperatures (90). The species compositions of aquatic communities will change with increasing water temperatures. Many water bodies, such as the Chesapeake Bay, will probably become poorer in terms of diversity and size of harvest (50). Other water bodies could become more productive, e.g., populations of warm-, cool-, and cold-water fish in the Great Lakes are expected to increase because of longer growing seasons, although biological diversity overall could decline (61). Forest pests and pathogens may spread (74). Tropical livestock diseases, such as Rift Valley fever and African swine fever, will be more likely to spread (73).

Increases in the incidence of several human diseases and parasites could result from the northward movement of their vector species in the United States. These include:

1. ascariasis, caused by the nematode *Ascaris lumbricoides;*
2. Chagas' disease, caused by a protozoan parasite *(Trypanosoma cruzi)* transmitted by temperature-sensitive insects *(Triatoma* sp.) (28);
3. dengue, caused by a virus carried by the temperature-sensitive mosquitoes *(Aedes aegypti, A. albopictus,* and *A. triseriatus);*
4. malaria, caused by *Plasmodium* spp., with mosquito vectors *(Anopheles* spp.); and
5. arthropod-borne encephalitis, a group of viral diseases carried by a variety of mosquitoes (55).

Rapid ecological changes set the stage for speeding up the process by which new diseases emerge or by bringing humans in contact with new agents (83).

Today's biological communities will break apart as some species relocate or are lost and others are added (74). These newly re-sorted biological groups could be more vulnerable to further invasions by NIS (49). Some observers predict that climate change could become the dominant driving force for new biological invasions in the next century (26). Assuming climate change occurs, and significantly affects North America, the changing biological communities will greatly complicate issues relating to NIS, compelling increasingly difficult decisions (21).

Understanding the complex forces that drive large-scale movements of animal and plant populations will be critical to unraveling particular invasions (56). But, in one scientist's view, ''it is hopelessly optimistic to expect that the scientific understanding that can be obtained over the next 100 years will enable us to predict the kind and extent of changes in the distribution and abundance of dominant plant species' (21). Others are less pessimistic regarding biologists' predictive capabilities (49). Several studies outline at least

Understanding the rapid spread of non-indigenous species such as dyer's woad (Isatis tinctoria) *might help predict and manage the biological shifts that would accompany global climate change.*

the general effects of unprecedented warming on future species ranges and different ecosystems (99,1 13)$

Global climate change would also scramble policies related to NIS. Under the commonly used historical definition of indigenous or its equivalents, a individual becomes non-indigenous when it leaves its species' range at some particular point in time. That time would need to be steadily reassessed for this definition to remain meaningful during climate changes. Otherwise, an increasing proportion of species would be considered non-indigenous, ''exotic, ' or "alien' and subject to the statutes, regulations, and policies that use these terms.

Under OTA's definition (ch. 2), an individual remains indigenous as long as it is within its species' natural range or natural zone of potential dispersal—areas determined in the absence of ''significant human influence. ' Natural ranges and zones can and do change over ecological and evolutionary time. Climate change would alter the specific location of species' ranges and dispersal zones but species would retain their designation as indigenous if their movements were treated as ''natural. For this definition to remain meaningful, there must be some way to distinguish between phenomena that involve lesser and greater human intervention. This is increasingly difficult.

In time, global climate change could render both definitions obsolete, along with policies based on them. Therefore, management and policy flexibility is likely to be increasingly important. A number of options regarding species movement have been suggested. Each presents difficult, and often expensive, choices. Many lessons learned from managing harmful NIS could inform such choices. These include decisions to:

1. Block Species' Movements---Managers might want to block movements of particularly harmful species. However, USDA's $6 million attempt to slow the African honey bee's *(Apis mellifera scutellata)* advance in southern Mexico has proven impractical (77). It is not clear whether other such efforts would be more successful.

2. Conduct Intensive Habitat Creation or Restoration—Managers might try to create artificial habitats for some species unable to adjust on their own (8). This could also entail controlling invaders from the south or lower elevations (70). However, the science of ecological restoration is in its infancy (ch. 5), managers would face great difficulty in anticipating changes and implementing plans (21), and some sites may change so much that habitat restoration or creation is impossible,

3. Provide Movement Corridors and New Protected Areas--Farmland, highways, cities, forest clear cuts, and other human-made areas can interrupt the movement of populations adjusting to climate change. Managers might acquire and maintain either movement corridors through these areas or new protected areas (74). Movement corridors might provide new pathways for harmful species as well (85), however. The practicality of corridors is not known because few have been intentionally created and studied. Data on pathways for harmful NIS might suggest plausible approaches,

4. Translocate Species-Impassable barriers to population movements may compel managers to physically move individual organisms, or their germ plasm (70). Perhaps only a few commercial, recreational, or otherwise popular species would receive the political and financial support for such expensive efforts. Unanticipated ecological and economic consequences could result from releases into new environments, as have other releases discussed in this report. Large-scale species translocations to prevent extinction remain largely theoretical.

5. Emphasize Ecosystem Functions-Managers might aim to preserve desirable ecosystem services-such as erosion control or providing forage, timber, or other commodities-rather than preserving particular species or communities (89). In some cases, NIS maybe the only species capable of providing these services during climate change. However, little is known about the fictional substitutability of species, in part because many critical species are decompose microbes and soil invertebrates (112).

Expanding international trade and other 20th Century changes have increased the numbers of species being moved worldwide. Climate change would be likely to accelerate these trends further. Many more species would be shifting ranges and people could have additional reasons to import and release species into new areas. Climate change is the wild card in predicting the future status of NIS.

WRAP-UP: THE CHOICES BEFORE US

Certainly parts of the future pictured in this chapter will come to pass—the trends toward loss of indigenous species and greater global movement of non-indigenous ones are firmly in place. These trends may be slowed but they would be very difficult and costly to reverse. As a result, some observers find that a profound transition is under way. The metaphors that guide natural resource management are shifting-from the self-sustaining wilderness to the managed garden (27. The world is being defined more in terms of the “unnatural” rather than the “natural” (82). This change is just one part of a general trend toward a more managed globe, whether such management relates to trade, pollution, telecommunications, or international conflict (17). To some, this shift represents a grave loss. To others, it represents greater willingness to undertake responsible action. Issues regarding indigenous and non-indigenous species underscore these different points of view.

In thinking about the future, the distinction between forecasts and visions is significant. Forecasts are concerned with the probable and possible. Much of this chapter, and this report, resides in that analytical realm. Visions, however, appraise the desirable, the imagined, the intended, and compelling (1 14). In their best-case scenarios, OTA’s Advisory Panelists envisioned a future in which beneficial MS contributed a great deal to human well-being, indigenous species were preserved, and harmful MS were brought under control (box 10-D). Much of this report is designed to provide the background and means for Congress to achieve such a vision. But deciding the vision’s worthiness-and choosing whether to pursue it—are not choices that science can make. Nor does nature provide answers. Which species to import and release, which to exclude, and which to control are ultimately cultural and political choices--choices about the kind of world in which we want to live.