THE OTA REPORT ON HARMFUL NONINDIGENOUS SPECIES[1]

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ABSTRACT. At least 4,500 species of foreign origin have established free-living populations in the United States, of which about 15% cause severe economic or environmental harm. Between 1906 and 1991, just 79 species caused an estimated $97 billion in losses. Virtually every economic sector and area of the country is affected, with some of the biggest problems in the east. Usually, exotic species reach the United States with human help, often via international trade. Rates of entry fluctuate, but never drop to zero—creating an even-greater economic and environmental burden. Neither domestic policies nor international agreements have been very successful when it comes to preventing new problems and managing old ones.

Background: OTA in Cyberspace

In October 1993, the Congressional Office of Technology Assessment (OTA) released "*Harmful Non-Indigenous Species in the United States*." This report synthesized, for the first time, the status of such species, their impacts, and related policies across geographic, taxonomic, and institutional lines. Because of the report's popularity and because Congress abolished OTA in 1995, only a few printed copies are available in federal respository libraries. However, the report can be downloaded from two web sites[2]. Also, it is part of a 1996 set of CD-ROMs containing OTA's entire 24-year body of work.[3]

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[2]The Princeton University web site contains all of OTA's reports plus additional material related to the agency's closing—http://www.wws.princeton.edu/~ota/. This site duplicates material on the "OTA Legacy" CD-ROM. The National Academy of Sciences web site contains text (without photogaphs) of OTA reports published by the Government Printing Office in its final 3 years: http://www.ota.nap.edu/l

[3]The "OTA Legacy" CD-ROM sells for $23 at the Government Printing Office (Stock No. 052-033-01457-2; telephone orders: 202/512-1800; FAX orders: 202/512-2250; mail orders: Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7974).

The 400-page book contains information on deciding wheher species are likely to be harmful; state and federal law; how nonindigenous species relate to genetically engineered organisms; the activities of federal agencies; details of species' impacts; and original data on a variety of topics, e.g., a list of new introductions between 1980 and 1993, the range of environmental education efforts underway, and exemplary state efforts.

Some things have changed for the better since the report was published. Two new federal interagency groups meet regularly to discuss exotic weed issues. One has worked hard to develop a national strategy. The 1990 law on indigenous aquatic species was reauthorized last year. The Nature Conservancy, Audubon Society, Brooklyn Botanic Garden, and others, published educational material on invasive plants. A number of regional studies are available on the Chesapeake Bay, San Francisco Bay, Florida, and California's wilderness areas and wetlands. On the other hand, some new exotic pests are making headlines, old ones have spread, and none have figured prominently in discussions of foreign trade agreements. OTA's analysis is a reminder that severe problems need correcting—fast. We can no longer claim ignorance of the problems and their scope.

Economic and Environmental Impacts

From 1906 to 1991, just 79 harmful exotic species caused documented losses of $97 billion, mostly in control costs and losses of marketable goods (Table 1). A worst case scenario for 15 potentially high-impact exotics adds another $134 billion in future losses. These species belong to every taxonomic group. They affect many national interests: agriculture, forestry, industry, human health, and natural areas. A single species, such as the zebra mussel, can cause massive losses for both private and public sectors, e.g., to public utilities, which must unclog water intakes; to landowners, who must clean irrigation channels; and to fish and wildlife agencies, which maintain the health of aquatic systems.

Zebra mussels, gypsy moths, imported fire ants, and a few other invasive pests, typify just one type of nonindigenous species, the type most likely to show up in economic data. They are highly visible; they are subject to special exclusion or control programs; and their economic costs are readily identifiable. Many harmful exotic species do not fit this model. They may be visible only to experts, if at all; usually no control is attempted; and their impacts are not easily quantifiable. Total cumulative costs have rarely been compiled even for the first group, and the second has been largely ignored. Therefore, any cost estimates represent only a fraction of the total. When estimates for nonindigenous agricultural weeds are factored in, for example, current annual costs are likely to reach several billion dollars, more in high impact years.

Environmental impacts are more difficult to quantify than economic ones. Nevertheless, they can be severe and harmful nonindigenous species have exacted a significant toll on U.S. ecosystems. These effects range from wholesale ecosystem changes and extinction of indigenous species to more subtle ecological changes and increased biological sameness. The introduction of nonindigenous species is closely correlated with the disappearance of indigenous ones in Hawaii and on other islands. Elsewhere, species that alter fundamental ecosystem properties may have as much, if not more, long-term impact. For example, melaleuca in the Florida Everglades system has converted grasslands and other natural areas into single-species forests. Wild hogs have damaged forest understory in the Great Smoky Mountains National Park. In the west, cheat grass invasions have

changed both the magnitude and frequency of wildfire. This, in turn, has altered the grasslands' hydrology and nutrient flow, accelerating further changes in species composition.

Current Numbers and Rates

The cumulative number of foreign nonindigenous species in the United States has climbed steadily and swiftly in the past 200 years (Fig. 1). At least 4,500 nonindigenous species of foreign origin have established free-living populations in the United States. This is surely an underestimate. Scientists in Florida will publish a detailed look at the state's situation this year. They show higher numbers for established exotic fish; amphibians and reptiles; and birds. For example, the number of established amphibians and reptile species has been revised from 25 to 36 species.

On average, 15% of foreign species trigger severe economic or environmental damage and about 40% cause some harm. Once troublesome species become established, they are rarely eliminated and new ones are constantly added. From 1980 to 1993, more than 200 foreign species were first introduced or detected in the United States. At least 59 of these are known or expected to be harmful. No one officially tracks newly introduced species. OTA's attempt was limited so these numbers are probably low, too.

The rate of harmful introductions fluctuates in response to social, political, and technological factors. New state and federal plant quarantine laws slowed the introduction of insect pests and plant pathogens after 1912. The switch from dry to wet ship ballast decreased weed introductions, but increased those of aquatic organisms. The rate of new introductions does not appear to be increasing in this century, although it is far higher now than natural rates and rates in the last century. The rate never drops to zero and the cummulative effects of current nonindigenous species are much like compound interest. In a number of states, nonindigenous plants now comprise 10, 20, or even 30 percent of the flora. In Hawaii, at least one-half of the state's wild plants and animals are nonindigenous. Together, harmful nonindigenous species create an ever-growing economic and environmental burden for the country.

Pathways of Introduction

Species first reach the United States by many pathways, but usually with human activity, transport, or the habitat modifications that provide new opportunities for species' establishment. Numerous harmful species arrived as unintended byproducts of cultivation, commerce, tourism, or travel. For instance, numerous European insects were first detected in Rochester, New York, when the city supported an extensive nursery industry and large numbers of plants were routinely unloaded there.

Nonindigenous species contaminate bulk commodities, packing materials, shipping containers, or ships' ballasts. In one survey, at least 367 distinctly identifiable taxonomic groups of plants and animals were found in the ballast water of ships arriving in Oregon from Japan. The chance for importing pests with unprocessed wood continues. The current Asian longhorned beetle outbreak in New York is likely a result. This insect is attacking maples and horsechestnuts. In China, it attacks hardwoods like elms, poplars, and willows. Weeds continue to enter the country as contaminants with seed; both plant and fish pathogens have arrived with diseased stocks. Some new species stow away on cars or other conveyances, including military equipment.

Other harmful alien species were imported as crops, ornamentals, livestock, pets, or aquaculture species—and later escaped. Of the 300 weeds of the western United States, at least 36 escaped from horticulture or agriculture. A number of invaders were imported and released for seemingly beneficial roles in soil conservation, fish and hunting, or biological control, and turned out to be harmful. A few illegal introductions also occur.

Different groups of organisms arrive by different pathways. Some fish are imported to enhance sport fisheries; others are illegally released by acquarium dealers or owners or escape from aquaculture facilities. Insects and aquatic and terrestrial mollusks usually hitchlike with plants, commercial shipments, baggage, household goods, ships; ballast water, or aquarium and aquaculture shipments.

Far more is known about pathways of foreign species into the United States than the routes by which nonindigenous species have spread beyond their natural ranges within the country. Once here, exotics spread both with and without human assistance. For example, a 1989 survey found that cabbage seedlings shipped to New York from Georgia, Maryland, and Florida, were infested with an average of up to eight larvae of the diamondback moth per hundred plants. The recent 12-state outbreak of rabies in the northeast have been traced to Florida raccoons which were moved to West Virginia in 1977. Double-crested cormorants are now an indigenous host for the previously foreign velogenic Newcastle disease. An estimated 5,000 birds died from western Nebraska to eastern New York in 1992.

For most established or recently detected exotics, little systematic reporting occurs and control efforts are uneven. Species that are commercially distributed or officially recommended for various applications can spread especially quickly. Whatever their route of arrival, highly damaging species now occur throughout the country in patterns that change constantly.

On average, 12 percent of intentional introductions - which usually receive at least some screening - cause harm. The comparable figure for unintentional introductions is 44 percent. For fish, mollusks, and terrestrial vertebrates, though, intentional introductions are harmful in about the same or greater numbers than unintentional ones. This suggests poor decision-making and/or complacency in screening for potential harm.

Decision-making standards are becoming more stringent and many introductions that were encouraged in the past are no longer allowed. However, there are still no reliable predictors of a given species' invasiveness so each decision about import and release is hampered by uncertainty. Three interrelated problems remain largely unsolved: determining levels of acceptable risk; setting thresholds above which more formal and costly decision-making approaches are invoked; and identifying tradeoffs when deciding in the face of uncertainty. Federal attempts to identify the risks of potentially harmful exotics have many shortcomings. Most regulatory approaches use variations of "clean" (allowed) or "dirty" (prohibited) lists of species or groups. Specific procedures vary in stringency throughout different agencies; risks to non-agricultural areas are often ignored; and generally, new imports are presumed safe unless proven otherwise.

Despite their limitations, efforts to prevent new introductions of harmful species are the country's first line of defense. Port inspection and quarantine are imperfect tools so prevention is only part of the solution. Some organisms are more easily controlled than intercepted. Aiming for a standard of

"zero entry" has limited returns, especially when prevention efforts come at the expense of rapid response or long-term control. When prevention fails—for technical or political reasons—rapid response is essential. The managers can choose to eradicate, contain, or suppress pests; these choices are not necessarily easy or obvious. The choice may be not to control already widespread organisms, or those for which control is likely to be too expensive and/or ineffective.

There are no "silver bullets" for control now and troublesome gaps may appear in the next 10 years. Chemical pesticides play the largest role in management currently, even for land managers that traditionaly have opposed widespread chemical use. In the future, an increased number of biologically based technologies will probably be available. These are slow to come on line, hampered by problems in balancing risk and regulation; in moving research to its application; in educating users; and in resolving commercial considerations. Development of new biological and chemical pesticides entail the same difficulties: ensuring species specificity, slowing the buildup of pest resistance to the pesticide, and preventing harm to non-target organisms.

Domestic Policies

At least 20 federal agencies are involved in some aspect of promoting, controlling, excluding, importing, or researching indigenous species. Each forms its own responses—responses that have been largely uncoordinated. The U.S. Departments of Agriculture and the Interior play the largest roles. Federal agencies manage about 30 percent of the Nation's lands, many with grim problems with exotic species. The Bureau of Land Management estimates that noxious weeds expand their acreage by 14 percent each year, or 2,300 acres per day. The National Park Service, with fairly strict policies regarding nonindigenous species, finds invasions threatening the very characteristics for which some parks were set aside.

State laws on nonindigenous species vary from lax to exacting and use a variety of legal apparatus. They are relatively comprehensive for agricultural pests, but only spotty for invertebrate and plant pests of non-agricultural areas. States play a larger role than the federal government regarding fish and wildlife. Several present exemplary approaches. Yet many state laws are weak and their implementation inadequate. Major U.S. laws also receive their share of criticism. Typically, they require cumbersome and time-consuming list-making and their application is not comprehensive.

Complaints regarding the work of federal and state agencies abound. States find it difficult to determine why and when federal programs begin and end. The federal government fails to stem a local or regional problem, unable to see it as an incipient national concern. Agencies respond too slowly to new problems. Earmarking for highly visible programs gets priority, risking that new pathways, and new types of problems will be neglected. Some agencies fail to screen plant imports for weediness and make problems worse. Generally, there is a lack of communication among policymakers and the effectiveness of many programs cannot be accurately assessed.

CONCLUSION

Many expect increasingly negative impacts from introductions of nonindigenous species. Global warming adds a wild card that could vastly alter patterns of species movement. These are forecasts,

based on nearly irreversible current trends. It is possible to envision a different future—one in which beneficial exotics contribute much to human well-being, native species are preserved, and harmful aliens are managed effectively. Deciding the worthiness of this vision is a cultural, political, even spiritual choice that will forever affect the biological heritage of the United States.

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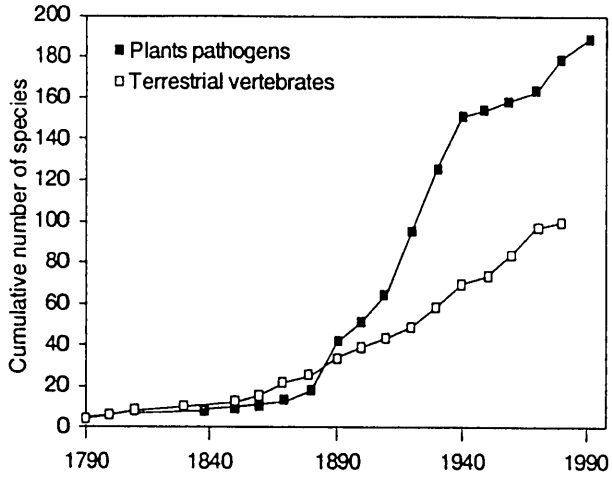
Table 1. Cumulative U.S. losses from selected harmful alien species, 1906-1991

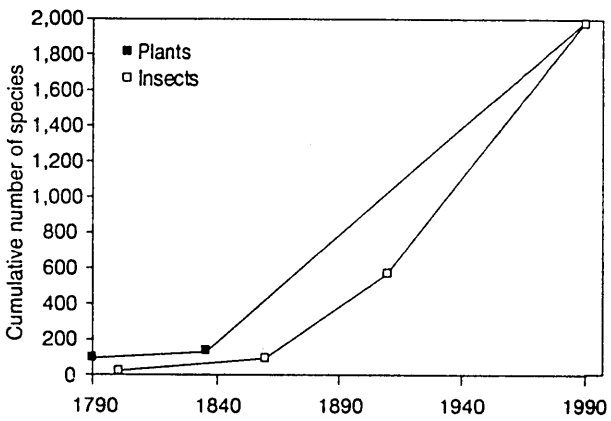
Category	Species analyzed (number)	Cumulative loss estimates (millions of dollars, 1991)	Species not analyzed[a] (number)
Plants[b]	15	603	—
Terrestrial vertebrates	6	225	>39
Insects	43	92,658	>330
Fish	3	467	>30
Aquatic invertebrates	3	1,207	>35
Plant pathogens	5	867	>44
Other	4	917	—
Total	79	96,944	>478

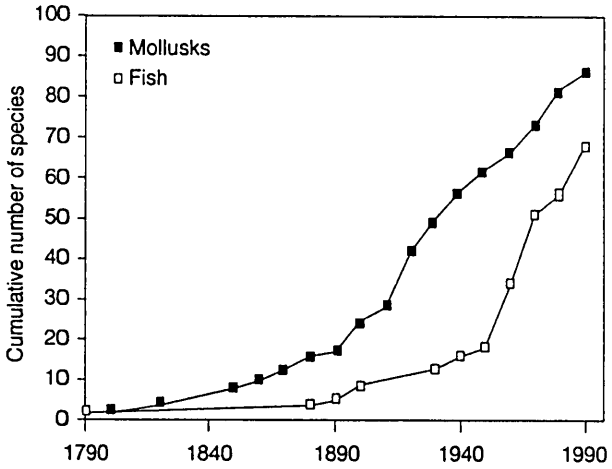
[a] Based on estimated numbers of known harmful species per category (figure 2-4).
[b] Excludes most agricultural weeds; these are covered in box 2-D.
NOTES: The estimates omit many harmful NIS for which data were unavailable. Figures for the species represented here generally cover only one year or a few years. Numerous accounting judgments were necessary to allow consistent comparison of the 96 different reports relied on; information was incomplete, inconsistent, or had other shortcomings for most of the 79 species.

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

Figure 1. Cumulative numbers of exotic species with foreign origins in the U.S.







SOURCES: Summarized by the Office of Technology Assessment from: J.C. Britton, "Pathways and Consequences of the Introduction of Non-Indigenous Freshwater, Terrestrial, and Estuarine Mollusks in the United States," contractor report prepared for the Office of Technology Assessment, October 1991; W.R. Courtenay, Jr., "Pathways and Consequences of the Introduction of Non-Indigenous Fishes in the United States," contractor report prepared for the Office of Technology Assessment, September 1991; K.C. Kim and A.G. Wheeler, "Pathways and Consequences of the Introduction of Non-Indigenous Insects and Arachnids in the United States," contractor report prepared for the Office of Technology Assessment, December 1991; R.N. Mack, "Pathways and Consequences of the Introduction of Non-Indigenous Plants in the United States," contractor report prepared for the Office of Technology Assessment, September 1991; Sailer, R.I., "History of Insect Introductions," *Exotic Plant Pests and North American Agriculture*, C.L. Wilson and C.L. Graham (eds.) (New York, NY: Academic Press, 1983), pp. 15-38; C.L. Schoulties, "Pathways and Consequences of the Introduction of Non-Indigenous Plant Pathogens in the United States," contractor report prepared for the Office of Technology Assessment, December 1991; S.A. Temple and D.M. Carroll, "Pathways and Consequences of the Introduction of Non-Indigenous Vertebrates in the United States," contractor report prepared for the Office of Technology Assessment, October 1991.

[a] Figure only includes data on species with known introduction dates for plant pathogens (n = 188), terrestrial vertebrates (n = 100), mollusks (n = 85), and fish (n = 68). Graphs for plants and insects are based on rough estimates.