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Report for Congress

Invasive Non-Native Species: Background and Issues for Congress

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Summary

For the first few centuries after the arrival of Europeans in North America, plants and animals of many species were sent between the two land masses. The transfer of non-natives consisted not only of intentional westbound species ranging from pigs to dandelions, but also intentional eastbound grey squirrels and tomatoes. And for those centuries the remaining non-native species crossing the Atlantic uninvited and often unwelcome, were ignored if they were noticed at all. National focus on non-native species arose in the 19th Century, primarily over losses in agriculture (due to weeds or plant diseases), the leading industry of the time. A few newly-arrived non-natives, and new estimates of adverse economic impacts exceeding $100 billion annually, have sharpened that focus.

Very broadly, the unanswered question regarding non-native species is whose responsibility is it to ensure economic integrity and ecological stability in response to the actual or potential impacts of non-native species? As this report shows, the current answer is not simple, and may be "no one." It may depend on answers to many other questions: Is the introduction deliberate or accidental? Does it affect agriculture? By what pathway does it arrive? Is the potential harm from the species already known? Is the species already established in one area of the country? Finally, if the answers to any of these questions are unsatisfactory, what changes should be made?

The specific issue before Congress is whether new legislative authorities and funding are needed to address issues of non-native species and their increasing economic and ecological impacts. Such legislation could affect domestic and international trade, tourism, industries dependent on bringing in non-native species, those dependent on keeping them out, and finally, the variety of natural resources which have little direct economic value and yet affect the lives of a broad portion of the public.

In the century or so of congressional responses to harmful non-native species, the usual approach has been an *ad hoc* attack on the particular problem, from impure seed stocks to brown tree snakes on Guam. A few notable attempts have begun to address specific pathways (*e.g.*, ship ballast water), but no current law addresses the general concern over non-native species and the variety of paths by which they enter this country. A 1998 Executive Order takes a step in bringing together some of the current authorities and resources to address a problem that has expanded with both increasing world trade and travel and decreasing transit time for humans and cargo. Bills have been introduced on this subject in the 105th, 106th, and 107th Congresses.

This report compares an approach based on a species-by-species assessment, *vs.* one based on pathways of entry. It also assesses the choice of an emphasis on prevention *vs. post hoc* control and intra-state quarantine. It describes existing federal laws and federal agency roles, federal interagency cooperation, and the federal interaction with state governments. Finally, it outlines effects, costs, and issues surrounding 47 selected harmful non-native species.

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Overview and Current Status

The Size of the Threat

Brown tree snakes from the western Pacific threaten power utilities and communications on Guam and the Northern Marianas, and seem ready to invade Hawaii and harm its enormous tourism industry. Zebra mussels from eastern Europe clog intakes for urban water supplies and nuclear power plants in the Great Lakes and the Mississippi basin. Formosan termites devastate living trees and historic buildings in New Orleans' French Quarter. Leafy spurge slashes the forage value of western grazing land, thereby creating precipitous drops in land value. Voracious snakehead fish from China appear in a pond in Maryland, precipitating drastic measures by state officials to keep them from spreading and destroying many of the region's freshwater fish.

To continue with a full list of the damaging effects of harmful non-native plants and animals risks sounding like hyperbole. Only in fairly recent years have many people realized that various areas of the country share problems that are similar in outline if not in detail. Impacts have been particularly severe on agriculture. The globalization of trade, the increased speed of travel, the massive volume of cargo shipments, and rising tourism all combine to increase the chance of more accidental introductions. Moreover, trade in exotic plants and animals that would have been impractical when voyages took days or weeks, now becomes practical when shipment times are only a fraction of that. Some of the species in the horticulture and exotic pet trades may escape or be released in the wild by accident or when owners tire of them.

All 50 states and all of the territories have at least some non-native plants and animals. A few (*e.g.*, Hawaii, Florida, Louisiana, Great Lakes states, California) have so many harmful non-natives as to cause major ecological and economic damage to a variety of locations and industries. Problems with terrestrial non-native species tend to be more severe in the southern half of the country in terms of total numbers of non-native species. Aquatic invasives have created more evenly distributed problems.

Dollar Impacts

Estimating the total economic impact of harmful non-native species is extremely difficult. No federal agency accumulates such statistics comprehensively. One

widely cited estimate put damage at $123 billion annually.[1] Including cost of control, damage to property values, health costs, and other factors, the following are the costs of selected species:[2]

- Leafy spurge (plant) — over $100 million annually
- Purple loosestrife (plant) — $45 million annually
- Formosan termite — $1 billion annually (including several hundred million dollars in New Orleans alone)
- Fire ant — about $2 billion annually (including $300 million in Texas alone)
- European green crab — about $44 million annually
- Zebra mussel — More than $750 million over 10 years (only for cleaning water intake pipes, filtration equipment, power generating equipment, etc., but not damage to docks, recreational or commercial boats, or other problems)
- Asian river clam — $1 billion annually
- Sea lamprey — $10-15 million annually for control only
- Brown tree snake — $1 million annually on Guam in power outages alone

Many impacts would be extremely difficult to measure in monetary terms. The West Nile virus has had a severe impact on populations of some wild birds, which are a major focus of recreation for millions of Americans. The introduction of lake trout into Yellowstone Lake (see *Gallery*, below), for example, is likely to have profound effects on populations of native cutthroat trout and, as a result, on grizzly bears, bald eagles, and other species. The presence of honeybee mites (see *Gallery*) is more problematic. On the one hand, crops pollinated by honeybees (itself a non-native species) will be more difficult to raise. On the other, species of native bees (bumble bees, carpenter bees, solitary bees, etc.), which are unaffected by the mites, may benefit from the absence of competition, and the presence of mites may be slowing the northward spread of Africanized honeybees, also a non-native species. And zebra mussels – one of the most costly invasives to date – have benefitted water quality in the Great Lakes region (see *Gallery*).

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[1] David Pimentel, Lori Lach, Rodolfo Zuniga, and Doug Morrison. "Environmental and Economic Costs of Nonindigenous Species in the United States." *BioScience*, January 2000, Vol. 50, p. 53-65. It represents one of the few attempts to date to provide comprehensive cost estimates. (Hereafter referred to as Pimentel report.) Costs estimates in the study included weeds, crop disease, rats, insect pests, non-native diseases of humans, zebra mussels, and a variety of other species and categories. Domestic and feral cats and dogs were included, and accounted for 4.9% and 0.1% of the total, respectively. Some have criticized the report as inflated, or as failing to count benefits of other introduced species.

[2] Each of these species is covered, in this order, in *A Gallery of Invasive Non-native Plants and Animals* at the end of this report; see these entries for documentation of economic impacts.

Major Laws and Executive Order

Because the problem of non-native species has continued to present itself as a series of seemingly disconnected crises, legislation has also become a patchwork, as each crisis was addressed. The laws addressing threats to agriculture (for centuries a well-developed North American industry whose risks from non-native invasions are relatively clear) tend to be more developed than laws protecting other industries, or ecosystems. In consequence, agencies whose mission is to address those risks are also better developed. Yet even there, responsibilities to protect agriculture from non-natives which are established in some regions but not others, are diffuse, shared, or even lacking. Moreover, the enormous volume of trade makes the burden on understaffed federal inspection systems so severe as to permit only limited or cursory inspections, and force a strong reliance on self-reporting by importers of living and non-living cargo.

Laws protecting the natural ecosystems on which such industries as tourism, the electric power industry, or city water supplies depend are far less developed. In some important instances, such laws scarcely exist at all. A state agency which wishes to bring in a sport fish from another continent to benefit its anglers may face few obstacles in doing so, much less a burden of proof to show that the action will not harm other economic interests, natural resources, or ecosystems.

No comprehensive U.S. law addresses imports of non-native species (see *Federal Laws* below for a summary of current statutory provisions). Some areas of interest lack laws altogether. No obligation lies generally with those importing living organisms (other than those already known to threaten agriculture) to show that the imported species is safe. Some laws force the burden of proof in the other direction: an import is deemed safe unless it is on a list of organisms known to be harmful. Special laws to control imports of exotic aquarium fishes or pets, and the disposal of those pets once owners tire of them, are lacking, or may be focused on some other issues (*e.g.*,

What's In A Name?

Many names have been used to describe species that are able to survive and reproduce outside the habitats where they evolved or spread naturally. Among them are *alien, exotic, injurious, introduced, invasive, nonindigenous*, *non-native*, and *noxious*. *Alien* tends to be applied to species from other regions that are also harmful and likely to proliferate wildly in their new habitat. *Injurious, invasive,* and *noxious* are generally used synonymously and are not confined to species outside of their normal range. These terms are applied to species that proliferate wildly, whether native (like white-tailed deer and barnacles) or non-native (like leafy spurge and brown tree snakes). In the legal arena, these terms are found in various laws and defined in various ways. This report generally uses the term *non-native* to emphasize the geographic origin of these species, but the term *invasive* is also used in deference to its increasing use among federal agencies.

This paper focuses on those non-native species which have caused or seem likely to cause substantial economic harm. The authors recognize that many species (*e.g.*, cattle, olives, wheat, tulips, etc.) were introduced with either little known adverse ecological impact, or with sufficient net benefits to make it likely that most people would not consider them harmful.

effects on populations of wild birds in the exporting country rather than in the United States).

Executive Order 13112. In response to rising concern, especially in southern and western states plus Hawaii, President Clinton issued Executive Order 13112 on Invasive Species (64 *Fed. Reg.* 6183, Feb. 8, 1999), revoking and replacing President Carter's 1977 Executive Order 11987 on exotic species.[3] The Executive Order seeks to prevent the introduction of invasive species,[4] provide for their control, and minimize their impacts through better coordination of federal agency efforts under a national invasive species management plan developed by an interagency National Invasive Species Council. The Order directs all federal agencies to address invasive species concerns as well as refrain from actions likely to increase invasive species problems. The National Invasive Species Council, supported by an advisory committee, was directed to develop recommendations for international cooperation, promote a network to document and monitor invasive species impacts, and encourage development of an information-sharing system on invasive species. (See *National Invasive Species Council* below for more information.)

Preliminary Options for A Complex Problem

Non-native species introductions can be divided into those which were intentional, or at least known by the person bringing in the living organisms, and those whose arrival was probably not known to the persons involved. While there may be disagreement over which species should be excluded among the many species whose entry is sought, there appears to be no constituency for *un*intentional imports. Rather, opposition results from the effects of regulations on trade or travel generally that might arise from efforts to prevent introductions. Therefore research on which pathways pose the greatest risks, and on the least intrusive mechanisms to reduce those risks, could offer substantial benefits with reduced harm to trade and travel.

However, with the possible exception of controls on ballast water and some agricultural pathways, little has been done systematically to identify or control additional high risk pathways. Congress may wish to consider requiring studies to (a) identify other high risk pathways; (b) identify (or create) suitable methods to prevent further introductions *via* these pathways; and (c) investigate methods to reduce inconvenience of control measures to travelers and shippers using those pathways. Untreated wood used in pallets, packing material, crates, and barrels; airline cargo holds; ship hulls, holds and ballast tanks; used tires, etc. are among possible targets for broader risk assessment or controls.

In contrast, intentional introductions present a different set of problems. Because many deliberate releases of non-native organisms have not been well-planned and have not taken into account the potentially injurious nature of the exotic

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[3] For more information on the legal status of Executive Orders, see CRS Report 95-772 A, *Executive Orders and Proclamations*.

[4] *Invasive species* are defined in §1 of the Executive Order as "alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health."

species, nor compared the potential risks with expected gains, some organizations have developed guidelines and codes of practice. The American Fisheries Society,[5] the International Council for the Exploration of the Sea, the World Resources Institute,[6] and the Food and Agriculture Organization of the United Nations[7] have prepared such guidelines to assist regulatory bodies and other groups in determining whether an introduction is justified, and then to advise them on what to do after an introduction is approved. These guidelines complement the legislation described later in this report by providing a conceptual framework for determining whether the risk of introduction is acceptable, and then suggesting quarantine, monitoring, and/or adaptive management if an introduction is approved. Components of these guidelines have been incorporated in national legislation in the United States and elsewhere.

Rapid response to news of a recent introduction of an invasive species is also an area being considered for improvement. In this respect, lessons might be learned from the National Interagency Fire Center (NIFC), primarily under the management of the Bureau of Land Management. Response to wildfires faces many of the same problems of haste, technical needs, and interagency and intergovernmental coordination. All federal land managing agencies participate in the NIFC, and a great deal of the program focuses on work with tribal, state, and local governments to bring many resources to bear on major fires. Somewhat similar problems are also faced at the federal Center for Disease Control and Prevention in Atlanta. Either program might provide models for congressional consideration.

Predicting an Invasion: Black and White?

Federal laws have tended to focus on exclusion, or "black lists," *i.e.*, on species that have already been shown to be harmful (anything not on the list is allowed), in contrast to a "white list" (anything not on the list is excluded). The black list can be prepared in various ways, but is usually made up of species already shown to cause serious damage to fisheries, endangered species, or (especially) agriculture.[8] An alternative approach would be to attempt to predict potential harm *before* a species' arrival. The prediction would be based on known characteristics of a species, such as how it reproduces, the number of seeds or offspring, etc.

A central dilemma, however, is the difficulty in making this prediction. What characteristics of seed dispersal, nesting, food and host preferences, etc., are most likely to lead to exuberant proliferation and result in economic and ecological harm? Even more fundamentally, of the many millions of species on the planet, which ones should be tested? For example, it seems logical that, all else being equal, plants

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[5] [http://www.fisheries.org/Public_Affairs/Policy_Statements/ps_15a.shtml]

[6] [http://www.wri.org/biodiv/b12-gbs.html#guidelines]

[7] Devin M. Bartley, R.P. Subasinghe, and D. Coates, *Framework for the Responsible Use of Introduced Species*, EIFAC/XIX/96/inf. 8. Report of the 19th Session, (Dublin, Ireland: European Inland Fisheries Advisory Commission, 1996).

[8] It should be noted that black lists do not readily address introductions by persons who are unaware that they are bringing in non-native organisms.

producing many seeds will be more invasive than those producing few seeds. The problem is that all else rarely *is* equal: a variety of factors affect "invasiveness." The abundant seed producer may require a special pollinating insect; the newly arrived plant with few seeds may leave behind its major herbivores, etc. A host of other factors may complicate prediction. No evidence to date has identified a suite of features in plants or animals that seems to be a truly reliable predictor of invasiveness, and thus many experts view all importations as suspect.

One observer argued that a somewhat reliable predictor is what he called "propagule pressure."[9] In very simple terms, this means that those species that "attempt" invasions (arrive in large numbers) most frequently and/or with the largest number of arriving individuals are most likely to have some success at invading. Scientists continue to model various factors which might contribute to invasiveness. Nonetheless, many scientists will likely prefer the strictest possible exclusionary policies, including white lists, because they lack confidence in these models.

In contrast, a number of industries depend in some respect on introductions of non-native species. These industries include florists as well as the horticulture, pet, and aquarium industries. They argue that a white list approach would exclude many species that were unlikely to cause harm, or else would require inordinate economic burdens on their industries to prove that a given imported species was safe. Further, paperwork to prove that an imported species was indeed one that was on the white list, could be burdensome as well. These groups strongly prefer a black list approach.

Whether a list is white or black, however, still implies that the importers actually know they are importing living organisms. An effort to prevent unintentional introductions would be compatible with any shade of list.

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[9] Mark Williamson, *Biological Invasions* (London: Chapman & Hall, 1996), Chapter 2, p. 28-54.

Threat of Harmful Non-Native Species

A variety of abundant non-native species have had severe economic impacts on U.S. industries and the natural environment. The increasing number of introductions and greater estimates of their cost are causing pressure on Congress to develop new responses to the problem. For example, according to a 1993 study by the Office of Technology Assessment OTA), just 79 of over 4,500 non-native plants and animals in the United States caused over $97 billion in damage between 1906 and 1991.[10] A more recent study estimated current damage from all of the species examined at $123 billion annually.[11] Damage varies by species, and can span an enormous range of effects, including power outages; loss of farmland property value; contamination of grain; spread of disease; increased operating costs; loss of irrigation water; collapse of buildings; competition with native plants; loss of sport, game, or endangered species; ecosystem disturbance; etc.

Some non-native plants have been notorious for years for causing both economic and ecological damage; kudzu, melaleuca, cordgrass, salt cedar, purple loosestrife, spotted knapweed, and Russian thistle are just a few examples of unwanted plants now causing ecological and economic harm in large areas of the United States. Their damage includes lowering water tables, poisoning humans and livestock, decreasing crop yields, and increasing pest control costs. A serious infestation can cause substantial losses in property values.[12]

Non-native invertebrate pests are also well-known: gypsy moths, Japanese beetles, Asian longhorned beetles, Asian tiger mosquitoes, fire ants, Africanized honeybees, and zebra mussels are among the most well-known. Introduced vertebrate pests (*e.g.*, walking catfish, lake trout, cane toad, brown tree snakes, monk parakeet, starlings, feral goats, bighorn sheep, nutria, rats, *etc.*) can also have serious economic and ecological impacts. These effects can also include the introduction of various human parasites and diseases.[13]

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[10] U.S. Congress. Office of Technology Assessment. *Harmful Non-Indigenous Species in the United States*. OTA-F-565. Washington, DC: U.S. Government Printing Office, September 1993, p. 3-5. (Hereafter referred to as "OTA Report.")

[11] Pimentel report. This study covered a broader array of species than the OTA report, and extrapolated estimates from available sources. (See Pimentel report for precise assumptions.) The arrival of more species since 1991 and a larger economy alone would be expected to increase damage substantially.

[12] A serious infestation of leafy spurge (*Euphorbia esula*) on an Oregon ranch caused a drop in property value from about $125-$150 per acre to $22 per acre over 10 years. (Federal Interagency Committee for the Management of Noxious and Exotic Weeds. *Invasive Plants: Changing the Landscape of America*. Washington, DC, p. 27; hereafter referred to as the "FICMNEW report.")

[13] While the transfer of human pathogens such as smallpox, syphilis, measles, AIDS, and malaria from continent to continent has enormous human, ecological, and economic consequences, human pathogens and parasites will not be covered in this report, though a few disease vectors (species that can transmit diseases to other organisms, but are not themselves pathogens) are mentioned.

In some of these cases (*e.g.*, kudzu, melaleuca, gypsy moths, Africanized bees, zebra mussels, and starlings), the source of the introduction is either known or strongly suspected. Introducers of some species, such as kudzu, melaleuca, and starlings, actually intended that their imports proliferate in the wild. Their purposes ranged from the practical (kudzu for erosion control) to the quixotic (starlings for a purported desire to bring all of the birds mentioned in Shakespeare's works to the United States). Whatever the motive, society itself was the loser in the importers' Faustian bargains as the organisms proliferated to the detriment of the economy, native fauna and flora, and ecosystems. Had they foreseen the damage these species would later cause, governments at all levels would probably have worked to prevent these introductions.

Introductions of non-native species may be intentional or unintentional. Some intentional introductions produced benefits (or at least low levels of harm), as in the case of the ring-necked pheasant, a game bird native to Asia. Unintentionally introduced species may be present for years or decades before their presence is even recognized, and the harm that they do, if any, is measured or observed.[14] However, catastrophic results can come from both accidental introductions (*e.g.*, zebra mussels), and intentional introductions (*e.g.*, hogs to Hawaii).

A wide variety of intentional introductions have had effects which, even if harmful to natural ecosystems or biodiversity, have produced economic benefits sufficient to cause acceptance of collateral damage. These include such food sources as cattle, wheat, honeybees, kiwi fruit, and soybeans, and such ornamentals as tulips, chrysanthemums, and dawn redwoods, to name only a few. In each case the introduction of these species was very much intentional and their propagation was more or less controlled. The economic benefits conveyed by these species are vast, and probably exceed the $123 billion figure cited above for the annual costs of non-native species.[15] U.S. agriculture would have a far different appearance if it were limited to the several dozen food crops known to have been cultivated in North America before 1492 rather than the hundreds of crops grown today. These non-native crops and their benefits are not the focus of this report, but should not be forgotten in discussions of those imported species which cause serious harm.

However, even in the case of non-native species conveying obvious benefits to humans, the introductions of non-natives are not without ancillary dangers, sometimes to the interests of those importing the target species: cattle can bring in seeds and new diseases, tubers can bring in insect pests, and soil from roots or hooves can harbor diseases for native plants. There may be damage to local ecosystems as they are deliberately modified to accommodate new plants or animals; in many cases (*e.g.*, tulip cultivation or chicken ranches), society has accepted

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[14] Measurements of the number of non-native species that do no harm is exceedingly difficult: by being innocuous, they escape study. Similarly, Kentucky blue grass (*Poa pratensis*, which, despite its common name, may have been an early import from Europe) now serves as important forage for native herbivores in much of the United States, and its benefits are equally hard to measure.

[15] No estimates of the benefits of desirable non-native species were found. A short discussion of industries and interests benefitting directly from non-natives is given on p. 23.

conversion of land to support these species. On the other hand, controversies over grazing rights for such non-natives as cattle and sheep show that acceptance is not automatic. Examples of these attendant risks and problems will be considered below. This paper will focus on species prone to (a) escaping human control or whose potential for escape is unclear, or (b) harboring or transporting other undesirable species. Predicting either of these risks is one of the most difficult problems in addressing invasions by non-native species.

Numbers of Non-Native Species in the United States

If a new kind of tree grows in the forest, no one hears of it, at least not for a long time. When new organisms are introduced to a new site, they must find conditions adequate to their needs, depending on the biology of the species (*e.g.*, food, rainfall, temperature, or mates), and must avoid predators and diseases. As a result, scientists agree, the great majority of biological introductions, whether caused by humans or occurring naturally, tend to fail. Of those that succeed, a small fraction become serious pests. A new species can exist in an area for decades without being noticed. For that reason, the number of non-native species counted in an area (if such counts are made) is likely to underestimate of the number of non-native species in the area.

So vast is this "bioinvasion" (as some have termed it), that only rough estimates can be made of the numbers of non-native species now in North America, much less the rest of the world. The 1993 OTA study cited above summarized information known then on the number of non-native species in the United States. (See **Table 1**.) It divided the species into those of foreign origin, and those of U.S. origin that had been introduced outside of their native ranges. As the OTA study noted, "These numbers should be considered minimum estimates. Experts believe many more [non-native species] are established in the country, but have not yet been detected." A more recent report estimated 30,000 non-native species in the United States.[16]

[16] Pimentel report.

Table 1. Estimated Numbers of Non-Native Species in the United States

Species with origins outside the United States		
Category	*Number*	*Percent of total species in United States by category*
Plants	>2000	unknown
Terrestrial vertebrates	142	~6%
Insects and arachnids	>2000	~2%
Fish	70	~8%
Mollusks (non-marine)	91	~4%
Plant pathogens	239	unknown
Total	>4542	
Species of U.S. origin introduced beyond their natural ranges		
Plants	unknown	unknown
Terrestrial vertebrates	51	2%
Insects and arachnids	unknown	unknown
Fish	57	17%
Mollusks (non-marine)	unknown	unknown
Plant pathogens	unknown	unknown
Total	>108	

Source: U.S. Congress. Office of Technology Assessment. *Harmful Non-Indigenous Species in the United States*. 1993. p. 92. Various original sources cited in report. Totals and percentages shown here are likely to be underestimated: entire groups of organisms (*e.g.*, many categories of non-marine invertebrates) are not included; other studies show higher numbers of non-native plants, etc. See text for discussion.

A Brief History of Introductions

The first human introduction of a non-native species into North America is lost in antiquity. Nomads crossing the Bering Strait brought their dogs with them over 10,000 years ago. Polynesians landed in Hawaii bearing pigs, rats, and crop seeds over 1500 years ago. Nearly a thousand years ago, Icelandic settlers in what is now Greenland brought cattle, sheep, and goats with them (and perished with them, possibly due to a reliance on European livestock unable to find fodder in an increasingly harsh climate). Corn, native to Central America, was spread over much of North and South America well before 1492. In the 17th Century, Puritan colonists

released domestic pigs into the New England forests to fend for themselves and provide food for the colonists. By the 1840s the descendants of the Puritan's pigs were as common "as grains of sand on the sea-shore" in midwestern forests.[17] The colonists also brought smallpox, measles, brucellosis, and other undesirables, to the severe detriment of native populations, both human and non-human. Some, like dandelions and Norway maples, have been in this country for so long that their non-native status is remembered largely by specialists.

According to the OTA report "[e]stimated numbers of [non-native species] in the United States increased over the past 100 years for all groups of organisms OTA examined."[18] Contributing factors include increases in the number of people traveling, the speed and methods of travel, trade generally, improved ability and speed in moving living plants and animals so that more of them survive the journey, the increase in modes of transport for hitch-hiking organisms (such as ship ballast water, pallet wood, and airplane wheel wells), the desire to have familiar sport and game animals in new areas, trade in horticultural and garden plants, trade in pets and aquarium animals, etc.

Geographic Origins of Non-Native Species

Plants and animals tend to survive best in a new site when that site is similar to their original habitat. Formosan termites arriving in New Orleans are much more likely to thrive than Formosan termites whose next stop is Anchorage, and a northern European grass seed traveling inside a prize bull is much more likely to survive in the Chicago area than the same species would in Miami. Thus, the plants and animals of northern Europe, Korea, northern China, Japan, and New England are more likely to be a threat to the stability of each other's ecosystems, than any of them would be to the fauna and flora of Miami or Singapore. Regions with similar climates and soils around the world are tending toward increasing biological homogenization as plant and animal species spread and the new arrivals thrive at the expense of natives. This reverses the normal evolutionary pattern of ever-greater species divergence between two geographically separated regions — from biodiversity to "biosimilarity" — as the new arrivals create a homogenized flora and fauna in the two regions.[19]

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[17] C. Dickens, 1842, p. 165 in *From Coastal Wilderness to Fruited Plain*, by Gordon G. Whitney. (Cambridge, England: Cambridge University Press, 1994.)

[18] OTA Report, p. 91.

[19] One author calls the phenomenon "evolution in reverse," though this can be misleading, since species themselves do not return to previous evolutionary forms. Rather *ecosystems* become more similar, contrary to typically increasing divergence. See Christopher Bright, *Life Out of Bounds: Bioinvasion in a Borderless World*. New York, NY: W.W. Norton & Co, p. 17 (1998). (Hereafter referred to as "Bright.")

Near neighbors[20] are less likely to be a source of pests. Canada, whose northern forests are contiguous with those of the United States, is not likely to be a source of forest pests, since its forests have no meaningful biological barrier separating them from our own. Consequently, if a native Canadian species could survive in a U.S. forest, it is probably already here. Similarly, desert plants of the southwest are probably shared with Mexico, and neither country's native desert fauna or flora poses much of a threat to the other.[21]

U.S. as Source of Non-Native Species

While the focus of this report is on species that are not native the United States, this country is itself a source of species which threaten ecosystems elsewhere. The grey squirrel of the eastern and northern states was introduced to Britain, where it has severely threatened populations of the English red squirrel. In 1958, Pan Am Airways and a local hotel introduced largemouth bass into scenic Lake Atitlan in Guatemala. The introduction led, in the next 25 years, to the crash of a sustainable crab fishery and of several native fish, contributed to the near-elimination of the commercial harvest of reeds used in local handicrafts, and forced the extinction of a bird found nowhere else. Moreover, the harvest of the bass has since plummeted.

And even at the ends of the earth, human fecal coliform bacteria contaminate McMurdo Sound, the major U.S. scientific research base in Antarctica. In an area thought of as earth's most nearly pristine environment, the bacterium *Clostridium perfringens* contaminates over 80% of sea urchins near the undersea outfall of the untreated sewage from the base. The scientist who discovered this contamination plans to study the effect, if any, this sewage contamination is having on the plants and animals of the Sound. Analysts have identified no laws designed expressly to prevent the spread and proliferation of U.S. species in other countries, except in agricultural areas.

Pathways of Invasion

To some extent, pathways of invasion between countries can be predicted. The arrival of zebra mussels and their attendant damage to city water supplies and electric utilities in the Great Lakes area focused much attention on the ballast water of cargo ships as a pathway for biotic invasion. Similarly, the propensity of brown tree snakes to hide in the wheel wells of airplanes has done much to focus attention on air stowaways. The recent arrival of Asian longhorned beetles may play a similar role in focusing attention on pallet wood, packing crates, live plants, and airport warehouses as pathways and centers of biotic invasion. In general, any arrival

[20] "Near neighbors" must be construed biologically. For example, a spiderling dispersed by wind might easily be blown from British Columbia to Montana. A freshwater clam or a deep soil insect would scarcely ever be transported naturally from one to the other.

[21] However, the statement does not apply to all ecosystems. For example, the higher elevation forests of the Sierra Madre in Mexico have been separated for millennia by hundreds of miles of desert from ecologically very similar forests of the Rockies. Pests, both plant and animal, could evolve in comparative isolation in these two areas, and be transported only recently with greater links of trade and traffic. Thus, the flora and fauna of either disconnected area could pose a threat to the other while the more continuously connected desert species are much less likely to do so. Moreover, non-native species may have invaded one area successfully without yet being found in the other; intervening desert could provide protection from invasion.

of living or untreated material (water, wood, soil, etc.) should not be overlooked as a possible pathway for biotic invasion. A comprehensive review of possible pathways, their risks, options for control, and research needs is, to the authors' knowledge, currently lacking.

Within countries, certain paths for species invasions are quite predictable. In the 19th Century, the railroads over which cattle were transported were a major path for the establishment of new plants. In the 20th Century, the zebra mussel quickly escaped the drainage of the Great Lakes (probably *via* the artificial connection to the Illinois River), and began its invasion farther and farther south into the Mississippi River drainage.

In addition to the accidental introduction of non-native species, introductions may occur from species deliberately brought into the country. In some cases, the importer does not intend for the imported plant or animal to escape to the wild, and in other cases, the purpose of importation is to promote its spread into natural habitats to achieve some desirable goal. In the first category are the imports of non-native pets and plants. The importer is hardly ever interested in seeing the imported organisms escape. But once the specimens are sold, control is lost, and purchasers sometimes release unwanted non-native fish from aquaria or garden ponds, for example, into local lakes or streams, often feeling they are doing a humane thing by letting the fish go.[22] A garden or greenhouse plant imported for horticulture may scatter shoots or seeds far more widely than expected. Water hyacinths, for example, were brought from South America in the late 19th Century as pool ornaments. The plant now covers thousands of acres in the southern United States, plus parts of Cape Cod and California, as well as parts of Africa and Asia. Moreover, the non-native animal or plant may harbor microorganisms that pose a danger to other species, even if the animal or plant itself does not survive in the wild.

People deliberately release organisms into the wild for a variety of purposes. Several species of fish were deliberately released into the Colorado River for sport anglers. (The continuing presence of these fish has been one complicating factor in efforts to recover threatened and endangered species in and along the river, as well as to manage the river more naturally.) Salt cedar (or tamarisk) was introduced from Central Asia into the desert Southwest in the early 19th Century, in part to control erosion along river banks. The tree now forms dense thickets on more than a million acres of riparian habitat. The thickets have generally little value for most native

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[22] According to one author, "By far the most ecologically disruptive sector of the pet industry is the aquarium trade... Of those exotic fish species established in the United States that are completely foreign to the country, about 65 percent arrived through the aquarium trade." (Bright, p. 162-163.). In contrast, the introduction of snakeheads (an Asian fish) began when they arrived alive to be sold in a New York City fish market. Two live fish were purchased and taken to Maryland where the buyer eventually decided not to cook them and so put them in an aquarium. When the fish got too big he released them into a nearby pond. They bred and their presence was discovered over a year later. See *Snakeheads*, below.

animals, and the trees are estimated to absorb more water each year than all the cities of southern California.[23]

Basic Methods of Pest Prevention and Control

The critical first line of defense against harmful non-native species is prevention of introductions, since success in controlling these species, once established, has been poor. Prevention is desirable from an ecological standpoint, and is usually economically advantageous, as most established non-native species cannot be eradicated, and controlling them to acceptable levels, when or if possible, is usually expensive.

Because many deliberate releases of non-native organisms have not been well-planned and have not taken into account the potentially injurious nature of the exotic species, nor compared the potential risks with expected gains, some organizations have developed guidelines and codes of practice. The American Fisheries Society,[24] the International Council for the Exploration of the Sea, the World Resources Institute,[25] and the Food and Agriculture Organization of the United Nations[26] have prepared such guidelines to assist regulatory bodies and other groups in determining whether an introduction is justified, and then to advise them on what to do after an introduction is approved. These guidelines complement legislation described later in this report by providing a conceptual framework for determining whether the risk of introduction is acceptable, and then suggesting quarantine, monitoring, and/or adaptive management if an introduction is approved. Components of these guidelines have been incorporated in national legislation in the United States and elsewhere.

Inspections and quarantines are key components of prevention by which the entry of non-native species *via* specific pathways might be controlled. This approach requires that species recognized as pests be listed and thus prohibited from entry.[27] Quarantines operate basically on either of two premises: (1) invest in strict control at points of entry (by which time, it could be too late to prevent entry) or (2) attempt to control what arrives (*i.e.*, try to act on the source or point of export or regulate the pathway of import). Ballast water management for ocean vessels is a means of "quarantine" whereby a major pathway of potential import for aquatic species is managed. A quarantine may also be posted on an area where a non-native species has been introduced, to prevent its further spread and promote its eradication.

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[23] Bright, p. 149.

[24] [http://www.fisheries.org/Public_Affairs/Policy_Statements/ps_15a.shtml] on October 24, 2002.

[25] [http://www.wri.org/biodiv/b12-gbs.html#guidelines] on October 24, 2002.

[26] Devin M. Bartley, R.P. Subasinghe, and D. Coates, *Framework for the Responsible Use of Introduced Species*, EIFAC/XIX/96/inf. 8. Report of the 19th Session (Dublin, Ireland: European Inland Fisheries Advisory Commission, 1996).

[27] For an overview of plant quarantine procedures and guidelines, see Robert P. Kahn, *Plant Protection and Quarantine. Vol. 1 Biological Concepts* (Boca Raton, FL: CRC Press, Inc., 1989), 226 p.

Inspections and quarantines for agricultural pests are a major responsibility of the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA). In addition, various states (particularly California, Arizona, and Florida) and territories conduct their own inspection programs aimed at agricultural pests. However, inspections and quarantines may not be effective for many species, especially non-target "hitchhiking" species, species which enter *via* uncontrolled or unrecognized pathways, and species that have invasive potential but are not yet recognized as pests.

Public education also plays a critical role in preventing the introduction of harmful non-native species. Campaigns have been relatively effective in educating the public about the hazards of bringing non-native plant species home from vacation, or releasing undesirable exotic pets or aquaria life into the wild.[28] Agriculture extension offices and the mass media are two generally effective means for distributing popular information to the public. In addition, the importance of educating specific groups, such as dock workers and vessel crew members, about controlling harmful non-native species could be emphasized, and might be integrated when possible with regulatory measures.

If exclusion and quarantines fail to keep a non-native species out of an area, and a species becomes established, the problem shifts to control of the pest, which includes preventing its spread between local areas and beyond any established perimeter. Control of harmful non-native species is divided into two related tasks: eradication where possible, and reduction to manageable/tolerable levels[29] where eradication is not possible. No single method of control is likely to be a panacea. Few control methods, if any, promise eradication under conditions where a species is well-established, but several methods, especially when used in combination and continuously, might reduce some target species' populations to tolerable levels.[30] Eradicating very small populations before they become established may be possible and is more likely if many methods are used intensively and in combination, including treating outlying populations as soon as they are discovered.

For introduced species, control methods include at least nine basic categories: (1) baits and attractants; (2) traps; (3) fumigants, repellents, and barriers designed for confined spaces; (4) herbicides and pesticides (conventional and biological); (5) biological control; (6) bounties and commercial exploitation; (7) cultivation control; (8) mechanical removal; and (9) site removal. To apply any of these basic strategies of control, substantial knowledge of the target species' behavior, biochemistry, dietary preferences, diseases, or other aspects of its biology is essential. The degree of species specificity of the selected approach can be a valuable asset in targeting control efforts. A number of species (*e.g.*, the brown tree snake and the

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[28] The extensive national public education program using "Smokey Bear" very effectively communicated the role that private individuals could play in preventing forest fires; Smokey's success may offer a model for preventing invasions of non-native species.

[29] Identification of what might constitute such a manageable/tolerable level is subjective, value-laden, and open to interpretation, depending upon who is affected.

[30] In the absence of eradication, control practices strive to be permanent, because residual pest populations could otherwise reproduce and return to problem levels.

Mediterranean fruit fly) have been the focus of several of these strategies. In addition, control program managers should be expected to solicit public input early in the process of formulating and evaluating control alternatives and to answer questions from the public about possible human health, economic, and other effects from control programs. The pros and cons of these nine strategies, and some of the information needed to apply them, are described below.[31] Comparatively more discussion is provided on biological control methods as they can sometimes involve the introduction of additional non-native species.

Baits and Attractants. Baits and attractants may be used to draw unsuspecting individuals of a target species toward a potential source of food or mates (see the additional discussion below on pheromones under "herbicides and pesticides (biological)"), where the target species can be counted, trapped, killed, or studied. Difficulties with baits and attractants commonly include sustaining a long-term monitoring effort and preventing harm to non-target species. Baits and attractants seem most promising when the area needing protection is well-defined with clear boundaries and has a significant density of the target species.

Traps. Trap use is limited primarily by cost, time required to service traps, and inability of traps to control target species over large areas. Various trap designs are available, and most are used in combination with some type of bait. For confined areas such as cargo holds, buildings, etc., traps may be relatively successful. On the other hand, traps have obvious drawbacks in open situations with either abundant alternative food or very low target species densities. Traps are comparatively safe to use, although they require some care when trapped individuals are killed and removed. Sticky traps have been used on rodents and brown tree snakes. Chinese mitten crabs have been trapped at irrigation screens during their downstream migration to spawn in saltwater.

Fumigants, Repellents, and Barriers Designed for Confined Spaces. Lethal substances can be used to target pests in confined areas or to prevent them from crossing a geographic bottleneck. These methods can be used either to create pest-free "islands" in a zone of infestation or to prevent invasive species from leaving an infested area *via* boxes, cargo holds, etc. Some species are known to avoid certain substances, such as tear gas or gasoline. Obviously, these substances can be used only to a limited extent in areas where there is infrequent human access, rather than in area-wide application. Fumigants can also be used to kill or exclude pests from confined areas, such as cargo containers. For example, the Environmental Protection Agency has approved methyl bromide[32] as a fumigant for the brown tree snake. Light is also known to repel some nocturnal animals. Submerged surfaces have been electrified at water and power facilities to discourage the settling of zebra mussel larvae and on ship hulls to inhibit barnacle settlement. Physical barriers can be used to prevent range extensions and access to new habitats, such as the electrical barrier

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[31] The discussion below draws heavily on U.S. Dept. of the Interior, *The Brown Tree Snake, Boiga irregularis, A Threat to Pacific Islands,* Biological Report 88(31), (Washington, DC: Fish and Wildlife Service, September 1988), p. 18-20.

[32] For more information, see CRS Report 98-590 STM, *Methyl Bromide and Stratospheric Ozone Depletion Policy Issues*.

being constructed by the Army Corps of Engineers in the Chicago Sanitary and Ship Canal to prevent or reduce the dispersal of invasive aquatic species between the Great Lakes-Saint Lawrence drainage and the Mississippi River drainage. Screens are used to prevent the movement of aquatic plant fragments within waterways. However, care is required to ensure that barriers do not impede the migratory behavior or natural dispersal of native species.

Herbicides and Pesticides. These chemical control agents can be subdivided into those derived from manufactured (conventional) or natural (biological) sources.

Conventional. Where chemical control is an option, herbicides and pesticides affecting or controlling only one or a group of related species are strongly preferable since broadly toxic substances risk substantial harm to non-target species. For example, TFM (3-trifluoromethyl-4- nitrophenol) is very specific in its toxicity to the larval stage of lamprey. Similarly, a variety of aquatic herbicides can be used specifically for the control of *Hydrilla* and water hyacinth. However, even if pesticides are highly specific, safety precautions often suggest the use of chemical control in conjunction with baits, thereby further reducing risks to pets, children, and other non-target organisms.

Biological. Biological herbicides and pesticides (also known as biopesticides) are derived from natural materials, such as animals, plants, bacteria, and certain minerals. At the end of 2001, there were approximately 195 registered biopesticide active ingredients and 780 products.[33] Biopesticides can be divided into three major classes: (1) **biochemical pesticides** are naturally occurring substances (*e.g.*, pheromones) that control pests by non-toxic mechanisms (*e.g.*, interfering with mating);[34] (2) **microbial pesticides** contain a microorganism (*e.g.*, a bacterium, fungus, virus, or protozoan) as the active ingredient, such as various types of the bacterium *Bacillus thuringiensis* (Bt) used to control certain insects harmful to cabbages, potatoes, and other crops;[35] and (3) **plant-incorporated protectants** are pesticides that plants produce from genetic material that has been added to the plant, such as when the gene for the Bt pesticidal protein is introduced into a plant's own genetic material causing the plant to manufacture the substance that destroys pests.[36] Although biopesticides tend to pose fewer risks than conventional pesticides (they

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[33] [http://www.epa.gov/pesticides/biopesticides/what_are_biopesticides.htm] on October 24, 2002.

[34] In some species (particularly insects), chemicals known as "sex pheromones" are given off that allow males and females to find each other. Sex pheromones work even when target species densities are low, and they are highly species-specific. For example, "Disparlure" (the commercially synthesized sex pheromone of the female gypsy moth) is used to trap male gypsy moths. Because it is sometimes difficult to determine whether a natural pesticide controls a pest by non-toxic means, EPA has established a committee to determine whether a pesticide meets the criteria for consideration as a biochemical pesticide.

[35] Public concern has arisen over the use of Bt in some situations (*e.g.*, for controlling Asian gypsy moths) because of possible adverse health effects that may occur in people with compromised immune systems.

[36] Both the protein and its genetic material are regulated by EPA; the plant itself is not regulated.

tend to be less toxic, usually are effective in very small quantities, often decompose quickly, and generally affect only the target pest and closely related organisms), users need to know a great deal about managing pests to employ them effectively.

Biological Control. A biological control organism competes with, preys on, parasitizes, or causes disease in a targeted pest species. Ideally, biological control agents attack the target species and no others.[37] Considerable knowledge of both the target species' and the control organism's basic biology and ecology is necessary to select a suitable control. Screening requirements vary for selecting biological control agents, with very stringent requirements for some uses, while requirements for other uses may be nonexistent. Together, individual state laws and APHIS (through 7 CFR 371) regulate the introduction of biological control organisms, and the USDA, through the Agricultural Research Service, administers a Biological Control Documentation Program.

A particular concern with biological control organisms is that they might commence feeding on non-target species once target species are sparse or eradicated. An example of this problem is mongoose introductions. In the 1600s, mongooses were introduced in Puerto Rico to eradicate rats, which they did with great success. Unfortunately, mongooses proliferated and began to eat a variety of birds and other native animals. Similarly, the house sparrow (*Passer domesticus*, or English sparrow) was brought from Europe to control the canker worm. This non-native bird now crowds out native birds and damages crops. In recognition of these problems, vertebrate animals with broad feeding habits are seldom, if ever, used today as biological control agents.

Production and release of large numbers of sterilized males has been particularly successful in controlling various insect pests (*e.g.*, medflies, screwworm flies, *Cochliomyia hominivorax*) and sea lamprey. Competitive mating by sterilized males results in lower reproductive rates for the invasive species population, reducing its abundance and potentially controlling population spread.

Using a disease or selective parasite may be an attractive option in some circumstances, but again there is a risk that the disease or parasite will attack non-target species. Fieldwork in a target species' native habitat is usually necessary to identify diseases or parasites to which the target species may be susceptible. Although the requisite research might be expensive, using biological control agents holds hope for long-term control. The alligator weed flea beetle (*Agasicles hygrophila*) for control of alligator weed (*Alternanthera philoxeroides*) and the current program using several beetles (*Galerucella pusilla, G. calmariensis,* and *Hylobius transversovitattus*) to control purple loosestrife are success stories for biological control of plants. The brown tree snake of Guam could be a possible candidate for biological control, since there is only one snake native to Guam and its habitat is quite different from the brown tree snake's. Thus, the chance of an introduced parasite or disease affecting the native snake species is minimal.

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[37] The USDA requires proof of host-specificity before supporting an insect introduction for non-native plant control.

Natural biological control can also occur through adaptive ecosystem response by native species to invasive species. An example is the indigenous weevil, *Euhrychiopsis lecontei*, which is a specialist feeder on northern water milfoil *(Myriophyllum sibiricum*). Once this weevil is exposed to the non-native Eurasian water milfoil (*M. spicatum*), it appears to change its feeding habits to preferentially feed upon the Eurasian variety. In Oregon, the native defoliating butterfly, *Vanessa cardui*, feeds on introduced thistles, *Cirsium arvense* and *C. vulgare*.

Other forms for biological control may involve planting competitive vegetation and managing livestock grazing. For example, grazing by sheep and goats can be an effective management tool for controlling leafy spurge.

Bounties and Commercial Exploitation. Under a bounty system, someone is paid to catch and kill the target species. High bounties may have to be paid to encourage sufficient control that results in a substantial effect on the target species' population. The problem, however, is that paying bounties can create a market incentive — a particular risk when a population dwindles to very low levels and prices go up or bounties are increased. In addition, these methods may have incidental adverse ecological consequences for native species arising from increased human traffic and collecting methods. In August 1999, the California Department of Fish and Game decided against permitting the commercial harvest of non-native Chinese mitten crabs, concluding that such harvest would not contribute to controlling this species and might encourage further introductions.

Cultivation Control. Use of such measures as timing of fertilizer applications, adjustment of planting dates, and crop rotation can be valuable management and control tools for invasive weeds. Some cultivation control methods, while minimal in cost and equipment, may require an additional commitment of labor and are unlikely to be effective unless combined with other control methods.

Mechanical Removal. Mechanical controls may be used to collect and remove large volumes of invasive non-native species, particularly plants. Mechanical harvesters may be used in the management of non-native aquatic vegetation, such as *Hydrilla* and water hyacinth, but are ineffective for control of these species on large bodies of water. Mechanical controls are also used to prevent the further spreading of established non-native species, and include methods such as cleaning of equipment (*e.g.*, during highway construction) and using certified weed-free seed and feed (*e.g.*, weed seeds have been mechanically excluded or removed). Mechanical control of terrestrial plants includes such basic procedures as hand-pulling and mowing. Some of these methods may require expensive specialized equipment or substantial commitment of labor to be effective.

Site Removal. The recently introduced Asian longhorned beetle (still perhaps at low enough levels to have some slight chance of being eradicated) is currently being controlled to some degree by removing all trees on which the pests might feed in neighborhoods where they have been found. Site removal has also been used in California to eradicate *Hydrilla* by draining small ponds and filling their depressions with earth. Such a drastic strategy would be unworkable if a pest becomes widely dispersed.

Unusually Susceptible Habitats

Harmful non-native species occur throughout the United States, but some ecosystems are more susceptible to invasion than others. Mild climate, geographic isolation, disturbance of the natural landscape,[38] and a high rate of exposure to non-native species are all factors which can make a habitat particularly susceptible to invasion. Islands and other long-isolated areas with unique plants and animals are also known to be particularly susceptible to invasive species.

Hawaii and Florida, for example, each have many threatened and endangered species and, not coincidentally, a plethora of harmful non-natives. Both states were long isolated biologically and have large numbers of native species found nowhere else. The mild climates of Florida and Hawaii make it easier for the rich flora and fauna from the rest of the tropical and semitropical regions to survive, and also make the states attractive to businesses that import and maintain or even breed non-native animals and plants, such as tropical fishes and ornamental plants. In Florida, the number of non-natives seemed overwhelming to a local reporter:

> In southern Florida, especially, untrammeled whims of humans have introduced so many species of non-farm animals (mainly as "pets") that the native fauna is greatly diluted. Running wild in Dade and Broward Counties have been piranhas, walking catfish, blue tilapia ("introduced from Africa in 1961 by officials of the Game and Freshwater Fish Commission"), electric eels, little barbed Amazonian catfish that swim up [human] urinary tracts, and other fish ("23 exotic fish now breeding in the wild"), Cuban anoles, iguanas, Asian water monitors, caimans, boa constrictors, pythons, mambas ("people want the newest animals as pets"), red-whiskered bulbuls, monk parakeets, howler monkeys, gibbons, green African savannah monkeys, crab-eating macaques, and a herd of 300 buffalo.[39]

Both Hawaii and Florida are major travel destinations and transportation hubs, so they are more likely to be subjected to inadvertent introductions. In both states, large areas have been cleared of native plants. It is often easier for non-native species to establish themselves in such disturbed habitats — in fact, many invasive species are weeds that have evolved to exploit such land and then "hitchhike" to freshly disturbed areas.

Another factor putting some environments at risk is the sheer number of opportunities for new introductions. Seaports, in which ships have exchanged ballast

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[38] Some writers argue that evidence is lacking on how disturbance affects susceptibility to invasions. But scientists generally accept the idea that severe depletion of an ecosystem's flora and fauna (*e.g.*, through fire, storm, volcanic eruption, etc.) does offer significant opportunities for newly arrived species, since the new arrivals face reduced competition in disturbed habitat.

[39] W. Belleville. "Critter patrol," *Florida* (a news magazine of the *Orlando Sentinel Star*), 29 May 1994: 8-12, 15. Some of this paragraph may reflect the reporter's view of the subject more than a strict interpretation of fact. For example, not all of the species mentioned actually reproduce in south Florida. In focusing only on exotic pets however, the paragraph understates Florida's problem.

water daily for decades or even centuries are at severe risk of invasions. Even if only a tiny proportion of newly arriving non-native species survive in the new habitat of San Francisco Bay, Chesapeake Bay, or Boston Harbor, the actual number of successful, invasive species may be very large. The areas around airports, with increasing volumes of international traffic and tourism, are also at risk. In addition, the greater the similarity of the point of origin, the more likely the invasion is to be successful. For example, biotic invasion of the Hawaiian islands is more likely to come from a plane originating in Guam than one originating in Anchorage.

Available Estimates of Costs and Impacts

It is difficult to quantify the damage due to invasive species. One study by Pimentel and his colleagues put annual costs and damage due to non-native species at $123 billion per year.[40] The study included no information about the overall costs of excluding non-natives. The assumptions used in the study to make these estimates may be questioned as over- or understating the costs; probably no two scientists or economists would make the same assumptions to derive such an estimate. As one of the first attempts to make a broad estimate over a very large range of species, the figure of $123 billion should be construed an informed estimate, and the interested reader should examine the report itself to assess the validity of the assumptions used to derive the figures.

The handful of species highlighted in this report alone cause annual losses over $3.5 billion, and two (Formosan termite and Asian river clam) are responsible for $1 billion each in control costs, diminished property values, and other damage. Even if new imports of non-natives were completely halted (a near impossibility), the costs of controlling established non-native species would continue.

The value and the cost of prevention are difficult to assess. In the absence of any other information, since the first several thousand harmful non-native species (*i.e.*, those for which any numbers could be gathered) collectively were estimated to cause about $123 billion annually in costs and damage, it seems reasonable to assume that the next several thousand to arrive and become established could cause comparable economic damage. Damage could include the same types of damage already known to affect economies and ecosystems through power outages; changes in flood regimes; increased erosion; loss of farmland property value; contamination of grain; spread of disease; increased operating costs; inefficient irrigation; higher risk of fire; collapse of buildings; loss of sport, game, or endangered species; ecosystem disturbance; etc.. There could also be effects on industries or ecosystems that have not yet been markedly harmed by non-natives (*e.g.*, the threat to fall tourism and the maple syrup industry in New England from Asian longhorned beetles, which attack and kill a variety of tree species, but are particularly fond of maple trees and their relatives).

Targeting each newly arriving non-native species individually seems very likely to be more costly than targeting pathways or groups of species. A focus on high-risk pathways could be more cost-effective over the long term, but a pathways approach

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[40] Pimentel report, p. 1.

itself has costs, as evinced by debate over the arrival of the Asian longhorned beetle. In an effort to stop or slow the entry of this widespread Asian species, controls were placed on its suspected major pathway — raw wood packing material of imports from China (rather than from all the Asian countries in which this species is common) and, for a time, the controls threatened a trade war with China. It also escalated federal government attention to the problem of non-natives to the highest levels of government. (See *Asian Longhorned Beetle*, below.)

Another cost of biological invasion is restoration of disturbed habitat, if it is undertaken at all. Damage due to an invasive species tends to rise as the species becomes established. Education of the public (which may stop the transport of many species before it even starts) can be relatively inexpensive on a per species basis. At each subsequent stage — transport, release, establishment, and spread — the cost of eradicating the non-native typically increases. And once the species is established over a wide area, eradication could be virtually impossible for any reasonably foreseeable sum. If a non-native becomes established and some local (and necessarily continuing) control occurs, restoration of the damaged habitat might be attempted, insofar as possible. Restoration could involve recruiting small armies of volunteers to pull non-native plants, hiring sharpshooters or trappers to kill or capture animals, transporting animals to native habitat, dredging streams and lakes, poisoning lakes, etc. Many restoration efforts could involve not only major costs but also substantial political controversy.[41]

The controversy illustrates the dilemma for policymakers. Specifically, the high cost to many industries (even seemingly unlikely ones, such as imported computer parts, steel, or other products with no obvious connection to living organisms), to economic interests, and to ecosystems from unwanted species is balanced against the costs of protective measures imposed on commerce in general. It will also have to be balanced against the needs of domestic industries (horticulture, agriculture, pet trade, etc.) that depend directly on importing non-natives.

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[41] The manager of one national wildlife refuge (in Hawaii) told one of the CRS authors that no control efforts at all would be attempted at that time in one distant area of the refuge that was overrun with non-native species, since only very substantial budget and time commitments would produce results, and any effort short of that would be a waste of money. Failing that, control efforts were instead directed to other areas with greater chances of success within available budgets. Restoration costs at that refuge might therefore be considered either zero — or completely insurmountable.

Industries That Benefit from Non-native Species

While the ecological damage from some non-native species can be great, only a small percentage of arrivals have proved to be economically harmful, and many are beneficial.[42] (For many species, the economic impacts are simply unknown.) Some industries rely heavily on non-natives. For example, nearly all food plants and animals in the United States are not native to the areas where they are now grown. Besides agriculture, industries relying significantly on non-native species include the nursery, aquaculture, and pet industries.

Most woody invasive plants in the United States were originally introduced by the landscape industry.[43] The giant hogweed, whose toxic sap can cause severe scarring, was introduced as an ornamental but escaped cultivation and is now widely listed as a noxious weed.[44] Similarly, water hyacinths were introduced, apparently as an ornamental for garden ponds. (See *Gallery*, below.) As a result of this and similar escapes, the nursery industry has been subjected to increasing criticism. States are increasing their regulation of potentially invasive species.[45] Some of those species are economically important to the nursery industry. Some industry groups have been working to develop voluntary controls to lessen the risk of inadvertent introduction of invasive plants.

Production from private aquaculture nearly tripled from 1985 to 1999 and was worth more than $987 million in 1999.[46] Many cultured species are not native. There is concern about the escape and establishment of cultivated species that may be harmful to native ones. Examples include the threat of Atlantic salmon in the Pacific Northwest; and the inadvertent introduction of diseases, such as dermo and MSX in oysters; or of other pest species. Concerns are similar for the aquarium and exotic pet trades, which rely heavily on tropical species. The United States is the world's leading importer of reptiles, for example, and though the chief concern has been for potential effects on source countries (*e.g.*, iguanas from Central America), there are concerns regarding possible escapes, especially in southern states.[47] A number of the species (some described in the *Gallery* below) were thought or known

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[42] Only a few commercial foods now grown in the U.S. are apparently native to this country. Known examples include sunflowers, Jerusalem artichokes, pecans, black walnuts, some wild cherries, strawberries, blueberries, and cranberries. Other familiar foods of the new world (*e.g.*, corn, potatoes, chilies, and tomatoes) either were not grown in this country in 1492, or were non-natives brought in earlier by Native Americans. For some foods, the native range is still debated.

[43] S.H. Reichard and C.W. Hamilton, "Predicting Invasions of Woody Plants Introduced into North America," *Conservation Biology*, vol. 11 (1997):193-203.

[44] Mary Robson, "The Perils of Giant Hogweed," [http://gardening.wsu.edu/column/07-05-98.htm], 5 July 1998.

[45] FICMNEW report, p. 86-91.

[46] U.S. Joint Subcommittee on Aquaculture, "U.S. Private Aquaculture Production for 1985-1999," October 2001. [http://ag.ansc.purdue.edu/aquanic/jsa/aquaprod.htm]

[47] Data from Traffic International [http://www.traffic.org/dispatches/archives/september98/], established to assist in the implementation of the Convention on International Trade in Endangered Species.

to have entered the United States as pets, or in association with pets: caulerpa, hydrilla, apple snails, goldfish, walking catfish, budgerigars, ring-necked doves, and common pigeons.[48]

Harm to the Natural Environment: Diffuse Responsibilities

Responsibilities for native flora and fauna and the ecosystems in which they live are scattered — the wards of many or of none. Generalized effects on ecosystems from very large to very small (*e.g.*, the Great Lakes, suburban trees, Texas lawns) are not the specific responsibility of one federal agency. With so many pathways for the entry of non-natives, so many possible entering species, and so many possible and nearly unknowable injured species, the natural ecosystem as a whole has no specific guardian. This scattered responsibility is a result of the evolving legal history of species protection,[49] agriculture, and import regulation.

U.S. law concerning native wild plants and animals is not a comprehensive body at the federal level. Under our system, inherited from English legal tradition, and stated very simply, the government regulates the "take" of native wild animals generally, and landowners control the native (and other) plants growing on their lands. A wild deer walking across a pasture does not "belong" to the landowner but is rather the government's to regulate; the bush it eats belongs to the landowner. Thus, colonial governments regulated native wild animals and, after the U.S. Constitution was ratified, the states retained the rights they previously had as colonies to control the wildlife within their boundaries.

Aside from special rules for lands owned by the federal government, federal native wildlife law can be thought of as a series of exceptions to the general concept that states regulate wild animals, and landowners manage (or don't manage) wild plants. Some of the major exceptions to that generalization include federal laws regulating the taking of migratory birds (pursuant to treaties), marine mammals, and endangered species. The great majority of native wild plant and animal species do not fall into any of these categories and therefore are not direct federal responsibilities under current law.

Native wild flora and fauna are frequently protected as a consequence of protecting something else — agriculture and endangered species, for example. Where there have been specific injuries to other industries or interests (utility intakes, for example). the pathway by which the harmful species arrived may be regulated to prevent other non-natives arriving *via* that pathway. Natural ecosystems, as result of the threats to other interests, may benefit from an incidental reduced risk of harm arriving by a pathway that is controlled.

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[48] For an overview of the risks of both plants and animals introduced from the aquarium trade, see [http://www.vetcentric.com/magazine/magazineArticle.cfm?ARTICLEID=1443].

[49] For a general discussion of early development of federal wildlife law, see *The Evolution of National Wildlife Law*, 3rd ed., by Michael J. Bean and Melanie J. Rowland (Westport, CT: Praeger Publishers. 1997), p. 7-14.

Federal Laws

Federal law concerning non-native species is scattered. No laws focus on the broad problems of non-native species, their interception, prevention, and control across a variety of industries and habitats. The body of law addressing non-native species and agriculture appears better-developed than laws relating to other sectors of the economy or the nation's natural resources. Some laws, though they do not directly address non-native species control or prevention, have effects that may limit such introductions. Below is a brief digest of existing laws, presented in chronological order of enactment, which affect non-native species introduction, prevention, and control. However, control of non-native species is not the major purpose of the law in some cases included below. In addition to federal laws, a number of states have laws restricting transport or possession of non-native species. State laws are not described in this report. Also omitted are the handful of federal laws referring to single species.

Lacey Act

Originally enacted in 1900, the Lacey Act (16 U.S.C. 3371-3378, 18 U.S.C. 42) makes it illegal to import, export, sell, receive, acquire, or purchase fish, wildlife, or plants[50] taken, possessed, transported, or sold in violation of U.S. or tribal law. In addition, this Act makes it unlawful to engage in interstate or foreign commerce involving any fish, wildlife, or plant material taken, possessed, transported or sold in violation of state or foreign law. Specific provisions authorize the federal government to prescribe requirements and issue permits for importing wild animals under humane and healthful conditions.[51]

One portion of the Act (18 U.S.C. 42) appears to give the Secretary of the Interior and the Secretary of the Treasury considerable power to exclude three major categories of non-native animals: vertebrates, crustaceans, and mollusks. Moreover, grounds for exclusion were expanded beyond the traditional harm to agriculture, horticulture, and forestry interests to include harm to "wildlife and wildlife resources." The inclusion of the latter could mean that nearly any non-native member of these groups could be considered for exclusion, since most and perhaps all ecologists would hold that the proliferation of any non-native species in an ecosystem risks harm to its wildlife resources. The reach of the law is somewhat unclear, however. Is the Secretary of the Interior to prepare a "white list" or a "black list"? In the 1970s, the Interior Department interpreted the provision as permitting

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[50] Plants are commonly covered under somewhat different provisions than animals are. To be covered under the Lacey Act, plants must be "indigenous to any state" and either protected under the Convention on International Trade in Endangered Species or under a state law protecting species threatened with extinction. Thus, a state like Hawaii apparently could not use the Lacey Act to help enforce that state's laws designed to keep out common native (mainland) plants. On the other hand, the Act might help the same state exclude animal pests from other states, whether native to the state of origin or not.

[51] The term "wildlife" can have various meanings in federal and state laws, including game species; game species except fish; mammals (rather than birds); or the entire animal kingdom.

a white list, and attempted to develop regulations accordingly. Public protest, chiefly from the pet industry but also others, stopped the process.[52] Current regulations, which adopt a black list approach and name only a small number of species to be excluded, are found at 50 CFR Part 16.

Animal Damage Control Act

The Animal Damage Control Act of 1931, as amended, (7 U.S.C. 426 et seq.) is the primary statute under which APHIS operates its Wildlife Services (WS) program (known until 1997 as the Animal Damage Control program). The Act gives APHIS wide authority to control wildlife damage on federal, state, or private land. WS is involved in protecting: (1) field crops, vegetables, fruits, nuts, horticultural crops, and commercial forests; (2) freshwater aquaculture ponds and marine species cultivation areas; (3) livestock on public and private rangeland and in feedlots; (4) public and private buildings and facilities, such as houses, commercial properties, swimming pools, golf courses, reservoirs, levees, and landfills; (5) civilian and military aircraft (against collisions with birds); and (6) public health (against wildlife-borne diseases such as rabies, Lyme disease, West Nile virus, and plague). WS control methods include providing advice to individuals and to municipal, state or federal agencies on a wide variety of preventive, non-lethal control methods. Control of predatory animals, native or non-native, is largely carried out by lethal means, including hunting, trapping, and poisoning.

WS also has cooperative agreements with the Fish and Wildlife Service (FWS), the National Park Service, the Bureau of Land Management, the Forest Service, and state natural resource agencies to help protect natural resources, including wildlife and threatened or endangered species, from loss of life, habitat, or food supply due to the activities of other species. Under the authority of the Act, as broadened by the Agricultural Appropriations Act of 2001 (P.L. 106-387), APHIS addresses damage problems caused by such non-native species as nutria, European starlings, and monk parakeets. Also in 1991, Congress passed P.L. 102-237, which (among other things) amended the Animal Damage Control Act specifically to add the brown tree snake to the list of animals that WS is charged to monitor and control.

Federal Seed Act

The Federal Seed Act of 1939, as amended (7 U.S.C. 1551 *et seq.*), requires accurate labeling and purity standards for seeds in commerce. Among other things, the Act prohibits importing and moving adulterated or misbranded seeds, and imposes labeling requirements. The Act also authorizes enforcement activities and rulemaking functions. In addition, this Act regulates interstate and foreign commerce in seeds, and addresses "noxious weed seeds" that may be present in agricultural

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[52] For a brief history of these actions, see Michael J. Bean and Melanie J. Rowland. *The Evolution of National Wildlife Law*, 3rd ed. (Westport, CT: Praeger Publishers, 1997), p. 53-55. These authors argue that the legislative history of the Act is unclear on the question of species-by-species lists. If white lists were permitted, the statute could be a powerful check on importing and transporting non-native animals in the three major taxonomic groups it covers.

(e.g., lawn, pasture) or vegetable seed. APHIS administers the foreign commerce provision of this Act; the Agricultural Marketing Service administers the interstate commerce provisions. The law works in conjunction with Plant Protection Act to authorize APHIS to regulate only imports of agricultural seed that may contain noxious weed seeds.

National Environmental Policy Act of 1970 (NEPA)

NEPA (P.L. 91-190, as amended; 42 U.S.C. 4321, *et seq.*) requires, among other things, that federal agencies consider and consult with the public about the environmental effects of their actions. The primary mechanism to achieve this end is the preparation of environmental impact statements (EISs) for major federal actions affecting the environment. Agencies are expected not only to prepare EISs, but also to comment on the EISs prepared by other agencies.[53]

This law could apply to some introductions of non-native species. If a federal action might affect the risk of introducing or spreading non-native species, thereby having a significant impact on the natural and human environments, the associated EIS would have to address this possibility. The limitations of NEPA *vis-a-vis* its application to non-native species include:

- limited applicability to actions without a federal connection;
- inapplicability to completed federal actions, although these actions may have effects that continue into the present;
- limited utility if the possibility of introducing non-native species is not foreseen; and
- the inability of scientists to provide agency administrators with the information necessary to assess the risks or consequences associated with introducing most non-native species.

If NEPA is invoked, the opportunity for significant analysis of a proposed action *via* an EIS is great. The resulting analysis may cause modification or abandonment of some actions or alternatives, if serious objections are raised. However, because NEPA is essentially procedural, it does not, by itself, prevent an activity, even if the risk of unfavorable environmental outcomes is high. Nonetheless, failure to consider the issue of non-native introductions could be grounds for requiring an agency to amend its EIS, thereby delaying the introduction and risk while the revision is prepared.

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[53] For an overview of NEPA, see CRS Report 97-49 ENR, *Summaries of Environmental Laws Administered by the Environmental Protection Agency*, p. 109-113. While the focus is on the responsibilities of that agency, the fundamentals of the Act are also explained.

Endangered Species Act (ESA)

The ESA[54] (P.L. 93-205, as amended; 16 U.S.C. 1531-1543) focuses its attention on species that are rare, not those that are common to the point of being weeds or pests. However, the strong protections offered under the ESA for rare species may provide a vehicle for regulating non-native species. For example, in the Pacific Northwest, the threat to resident salmon species protected under ESA is a major argument being used against the introduction or expansion of aquaculture for Atlantic salmon. Similarly, introduction of mountain goats in an area where they are not native would be more likely to be questioned if there are local endangered or threatened plants likely to be harmed by the goats.

ESA could provide protection in two ways. First, if the introduction were to be carried out by a federal agency or require licensing, financial support, permits, etc., from a federal agency, the agency involved would have to consult with FWS or National Marine Fisheries Service (NMFS) to determine whether the introduction (or action leading to introduction) would tend to jeopardize the continued existence of the listed species or adversely modify its critical habitat. If so, the introduction would usually be prevented or modified to reduce the risk. Second, if the action had no federal nexus, but its effects could result in taking (as defined in the Act) a listed species, the party carrying out the action would have to obtain an incidental take permit from FWS or NMFS.

Questions of knowledge, intent, and causality affect whether violations under the ESA have occurred and whether penalties may be applied. Therefore, as a practical matter, ESA is an unlikely alternative for penalizing the introduction of non-native species because the persons responsible for introducing many non-native species may never be known and introduction is often inadvertent. For example, it is not known who introduced zebra mussels, and it is likely that their probable introduction *via* ballast water was unintentional. In addition, introductions may go unnoticed for a long time, compounding the difficulty in determining responsibility. For example, the introductions of the brown tree snake on Guam went unnoticed for years after their arrival, though the brown tree snake is strongly suspected of being directly responsible for the extinction of several species on Guam. Consequently, enforcement actions under ESA in the usual sense are unlikely.

However, the policies of the ESA and the duty of federal agencies to ensure that federal actions will not jeopardize species listed under the Act may result in changes in certain practices and the tightening of regulation of potential pathways, *e.g.*, greater regulation of ballast water practices or design requirements for aircraft cargo holds to reduce the chance of biological stowaways. Although there may be some circumstances in which the ESA will play a role, Congress may see new laws more directly and better suited to the prevention of introductions as also desirable.

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[54] For more information about the ESA generally, see CRS Issue Brief IB10072, *Endangered Species: Difficult Choices*.

Federal Noxious Weed Act

Although most provisions in the Federal Noxious Weed Act of 1974 (P.L. 93-629) were supplanted by the Plant Protection Act (see below), a key section (7 U.S.C. §2814) still requires each federal agency to provide for noxious weed management on lands under its jurisdiction. The provision, introduced in the 1990 Farm Bill (P. L. 101-624, title XIV, §1453, 104 Stat. 3611) amended the Federal Noxious Weed Act to require federal agencies to establish and fund noxious weeds management programs through the agencies' budgetary process. It also allowed the agencies to implement cooperative agreements with state agencies regarding the management of undesirable plant species in areas adjacent to federal lands. The Act requires joint leadership from the Secretaries of Agriculture and of the Interior in coordinating federal agency programs for control, research, and education associated with designated noxious weeds. In 1994, a memorandum of understanding among several federal agencies created the Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW) as a vehicle to coordinate noxious weed priorities (see *Interagency Efforts*, below).

Nonindigenous Aquatic Nuisance Prevention and Control Act

The Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 (NANPCA; Title I of P.L. 101-646; 16 U.S.C. 4701, *et seq*.) established a federal program to prevent the introduction of, and to control the spread of, unintentionally introduced aquatic nuisance species and the brown tree snake. The Coast Guard, EPA, FWS, the Army Corps of Engineers, and the National Oceanic and Atmospheric Administration (NOAA) share responsibilities for implementing this effort, acting cooperatively as members of an Aquatic Nuisance Species (ANS) Task Force to develop a program for protection, monitoring, control, and research. The Task Force conducts studies and reports to Congress: (1) to identify areas where ballast water exchange can take place without causing environmental damage; (2) to assess whether aquatic nuisance species threaten the ecological characteristics and economic uses of U.S. waters other than the Great Lakes; (3) to determine the need for controls on vessels entering U.S. waters other than the Great Lakes; and (4) to identify and evaluate approaches for reducing the risk of adverse consequences associated with intentional introduction of aquatic organisms.[55]

Under NANPCA, state governors are authorized to submit (1) comprehensive management plans to the Task Force that identify areas or activities for which technical and financial assistance is needed; and (2) public facility management plans to the Assistant Secretary of the Army (Civil Works) that identify public facilities for which technical and financial assistance is needed. Grants are authorized to states for implementing approved management plans, with maximum federal shares of 75%

[55] See [http://www.ANSTaskForce.gov/accomp.htm] for accomplishments of the ANS Task Force.

of costs for each comprehensive management plan, and 50% for each public facility management plan.[56]

Under §1101 of NANPCA, a Great Lakes ballast water management program (voluntary in its first 2 years) became mandatory in 1992. This section directed the Coast Guard to issue regulations (33 CFR Part 151) to prevent the introduction and spread of aquatic nuisance species into the Great Lakes through the ballast water of vessels and established civil and criminal penalties for violating these regulations. The Act also encourages the Secretary of Transportation, through the International Maritime Organization, to negotiate with foreign countries on the prevention and control of the unintentional introduction of aquatic nuisance species. In addition, the Act directs the Corps of Engineers to develop a program of research and technology for the environmentally sound control of zebra mussels in and around public facilities, and make information available on these control methods. Subsequently, the Corps established a zebra mussel facility research program, including annual technical conferences and a publication series.

National Invasive Species Act

In 1996, the National Invasive Species Act (NISA; P.L. 104-332) amended NANPCA to create a national ballast management program modeled after the Great Lakes program wherein all ships entering U.S. waters (after operating outside the U.S. Exclusive Economic Zone) are directed to undertake high seas ballast exchange or alternative measures pre-approved by the Coast Guard as equally or more effective. While initially unenforced on a ship-by-ship basis, this national program was to have become mandatory within 3 years of the date the Coast Guard issued its voluntary guidelines[57] if ships did not show adequate compliance with the program[58] in the absence of enforcement. The National Ballast Information Clearinghouse (NBIC) was developed jointly by the Coast Guard and the Smithsonian Environmental Research Center to synthesize, analyze, and interpret national data concerning ballast water management. During the first 2 years (July 1999 through June 2001), the NBIC found that nationwide compliance with ballast exchange reporting requirements was low, with only 30.4% of vessels entering the U.S. Exclusive Economic Zone (EEZ) filing reports with the NBIC.[59] On March 4, 2002, the Coast Guard published an advanced notice of proposed rulemaking, seeking comments on development of a ballast water treatment goal and an interim ballast

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[56] Despite substantial authorizations, relatively little has been appropriated or made available for state grants to implement these management plans.

[57] 64 *Fed. Reg.* 26672-26690, May 17, 1999. These regulations are effective July 1, 1999.

[58] If the voluntary program does not result in sufficient compliance, reporting of ballast water management practices will become mandatory for nearly all vessels entering U.S. waters (33 CFR 151.2040). If necessary, the Coast Guard will promulgate further regulations to implement such a mandatory reporting program.

[59] G. M. Ruiz, *et al., Status and Trends of Ballast Water Management in the United States: First Biennial Report of the National Ballast Information Clearinghouse*, (Edgewater, MD: Smithsonian Environmental Research Center, Nov. 16, 2001), p. 4.

water treatment standard as part of regulations that would make guidelines for ballast exchange mandatory.[60]

NISA encouraged negotiations with foreign governments to develop and implement an international program for preventing the introduction and spread of invasive species in ballast water. This Act required a Coast Guard study and report to the Congress on the effectiveness of existing shoreside ballast water facilities used by crude oil tankers in the coastal trade off Alaska, as well as studies of Lake Champlain, the Chesapeake Bay, San Francisco Bay, Honolulu Harbor, the Columbia River system, and other estuaries and waters of national significance. It also authorized funding for research on aquatic nuisance species prevention and control in the Chesapeake Bay, Gulf of Mexico, Pacific Coast, Atlantic Coast, and San Francisco Bay-Delta Estuary.

Under NISA, a Ballast Water Management Demonstration Program was established to promote the research and development of technological alternatives to ballast water exchange. In addition, NISA modified the composition and research priorities of the Aquatic Nuisance Species Task Force; and expanded the zebra mussel demonstration program requirements. Research grants were required on environmentally sound methods for controlling the dispersal of aquatic nuisance species. In addition, the Corps of Engineers was directed to investigate and report to Congress on methods specifically for preventing and reducing the dispersal of species from the Great Lakes-Saint Lawrence drainage into the Mississippi River drainage through the Chicago River Ship and Sanitary Canal. In addition, research was authorized on the prevention, monitoring, and control of aquatic nuisance species in Narragansett Bay, Rhode Island.

Finally, NISA required the Task Force to develop and implement a comprehensive program to control the brown tree snake in Guam and other areas where the species has spread outside of its historic range.

NISA has been criticized as inadequate and faulted for several alleged shortcomings, including weakness in implementing some of its provisions.[61] Since NISA exempted most coastwise vessel traffic from ballast water exchange guidelines, vessels traveling short distances (*e.g.*, from San Francisco Bay, which is highly invaded, to Puget Sound, which is less so), and therefore likely to be carrying live organisms, are exempt from controls. With the exception of the Great Lakes, critics point out that no ecological surveys or management actions have been funded for inland waters such as the Colorado, Rio Grande, or Missouri Rivers. In addition, they claim that sections of NISA pertaining to invasive plant management have not been funded or used. Others are critical of the provisions of 16 U.S.C. 4711(k)(2)(A) giving the vessel owner a blanket exemption to ignore any mandatory regulations if the master determines that the vessel might not be able to safely conduct a ballast water exchange on the open ocean. Whereas earlier provisions applicable to the

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[60] 67 *Fed. Reg.* 9632-9638.

[61] Letter of February 11, 1999, to Hon. Carol Browner, Administrator of Environmental Protection Agency, from Representatives George Miller, Jim Saxton, and 16 other Members of the U.S. House of Representatives.

Great Lakes provided a safety exemption, the master of a vessel was required to report the problem to the Coast Guard and conduct alternate ballast water management measures, often negotiated on a case-by-case basis. Critics believe the NISA language has eliminated any incentive to change ballast water piping systems or adopt other management or treatment options to deal with the problem safely.

Alien Species Prevention and Enforcement Act of 1992 (ASPEA)

This law (P.L. 102-393; 39 U.S.C. 3015) makes it illegal to ship certain categories of plants and animals through the mail. The prohibited species are those injurious animals whose movement is prohibited under part of 18 U.S.C. 42 and those plants and animals whose shipment is prohibited under 16 U.S.C. 3372. (Both sections are part of the Lacey Act.)

ASPEA does not make any new categories of plants or animals illegal to ship, but rather makes it clear that use of the U.S. mail is included among those forms of transport whose use is illegal for shipment of prohibited species. PEA appears to do very little to prevent the introduction of non-native species, especially if the sender is unaware that the shipped items are prohibited under the above laws, but ASPEA does appear to add one more law to the arsenal under which prosecutors might bring cases involving shipment of various species, including non-native species, to court.

Wild Bird Conservation Act of 1992 (WBCA)

The WBCA (P.L. 102-440; 16 U.S.C. 4901, *et seq.*) does not focus on the prevention of invasions by non-native species, but rather on the conservation of birds caught in the wild in foreign countries and imported into this country. By regulating imports of certain wild birds, the WBCA may reduce imports of non-native parasites and diseases that could affect wild populations of native birds. Prevention of invasions would therefore be a potential effect of the law, rather than its purpose. It also could reduce the chance that an imported wild bird species could escape, breed, and increase to pest levels. Ten families of birds are specifically exempted from the provisions of the law, though their importation could be restricted by many other applicable U.S. laws.

Hawaii Tropical Forest Recovery Act of 1992

The Hawaii Tropical Forest Recovery Act (P.L. 102-574; 16 U.S.C. 4503(note)) amended the International Forestry Cooperation Act to create a variety of measures to address the problems of the native forests of Hawaii. The introduction of such non-native species as pigs, goats, and mosquitoes has been a major threat to the integrity of native Hawaiian forest ecosystems, and the Act has several features that address these issues. The Secretary of Agriculture is authorized to develop a program to assist Hawaii and U.S. territories, through the Forest Service, to protect native species from non-native species, and to establish biological control agents for the non-natives. The Secretary must also develop plans for the Institute of Pacific Islands Forestry and for the Hawaiian tropical forests which must, among other things, provide for the study of biological control of non-native species.

In addition, the Act created a short-term task force of specified federal, state, and other individuals. Among its other responsibilities, the task force was to develop an action plan to "promote public awareness of the harm caused by introduced species" and develop recommendations on "the benefits of fencing or other management activities for the protection of Hawaii's native plants and animals from non-native species, including the identification and priorities for the areas where these activities are appropriate." The report has since served as the framework for Forest Service management and research budget requests in this area. There has been a modest increase in funds to support invasive species research and eradication efforts, as well as a specialist to oversee management activities on invasive species.

Plant Protection Act of 2000

The Plant Protection Act of 2000 (PPA) (7 U.S.C. 7701 *et seq*.) consolidated several plant quarantine authorities, some dating back to the 1880s. It gives the Secretary of Agriculture the authority to prohibit or restrict the importation, exportation, and the interstate movement of plants, plant products, certain biological control organisms, noxious weeds, and plant pests.[62] The statute also gives the Secretary the authority to inspect foreign plant imports, to quarantine any state or premise infested with a new pest or noxious weed, and to cooperate with states in certain control and eradication actions. These authorities have been traditional hallmarks of U.S. plant pest regulations, and are administered by APHIS in collaboration with state departments of agriculture and their plant protection boards.

Traditionally, all states have some type of domestic quarantine laws but federal regulations preempt state actions in interstate commerce. The new Plant Protection Act, however, allows states to petition the Secretary for "special needs" exceptions to federal rules. Exceptions granted by the Secretary would allow states more control over movement of certain plant material across their borders. Regulations for applying the new petition process have not yet been issued, but the Secretaries still would retain the power to grant these "special need" petitions. The new law also allows individuals or states to petition the Secretary of Agriculture to add or remove plant pests from federal regulation. Regulation of foreign and interstate plant movement has been important to prevent or limit the spread of a harmful non-native species in the United States. The new law seeks to give more power to states to influence the list of invasive species that would be federally regulated.

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[62] The PPA became law in June 2000 as part of the Agricultural Risk Protection Act (P.L. 106-224). This law consolidated and superceded several U.S. plant health laws, including: (a) The Act of August 20, 1912 (commonly known as the "Plant Quarantine Act", 7 U.S.C. 151-164a, 167); (b) The Federal Plant Pest Act (7 U.S.C. 150aa *et seq*. and 7 U.S.C. 147a); (c) Section 102 (a) - (e) of the Department of Agriculture Organic Act of 1944 (7 U.S.C. 147a); (d) The Federal Noxious Weed Act of 1974 (7 U.S.C. 2801 *et seq*.), except sections 1 and 15 of that Act (7 U.S.C. 2801 note and 7 U.S.C. 2814); (e) the Joint Resolution of April 6, 1937 (commonly known as the "Insect Control Act") (7 U.S.C. 148 *et seq*.); (f) The Halogeton Glomeratus Act (7 U.S.C. 1651 *et seq*.); (g) The Golden Nematode Act (7 U.S.C. 150 et seq.); and (h) Section 1773 of the Food Security Act of 1985 (P. L. 99-198; 7 U.S.C. 148f).

The authority to impose quarantines has also been an important element of federal plant protection statutes. History indicates, however, that the outcome of domestic quarantines is seldom certain. For example, under the authorities of this Act and preceding ones, APHIS has for decades imposed quarantines to prevent the spread of imported fire ants, which can be harbored in the root balls of nursery plants or in sod and soil; its geographical range, however, continues to expand. On the other hand, the successful efforts to eradicate the Mediterranean fruit fly (medfly) in California and Florida, and those to prevent witchweed from spreading into Midwestern states attest to levels of success.

The PPA includes new authorities for controlling noxious weeds and for regulating biological control agents. Under the PPA, states and others have a statutory process to list or 'delist' pests and weeds based on 'science-proven' special local needs. The Act expands the definition of noxious weed to include any plant that could bring harm to agriculture, public health, navigation, irrigation, natural resources, or the environment. This new definition could potentially allow federal action on hundreds of invasive plant species not previously regulated. The old Federal Noxious Weed Act allowed regulation of a limited number of invasive weeds, restricting actions only against weeds "... new to, or not widely prevalent in the United States." Significantly, under the new law noxious weeds would now be treated as other plant pests in respect to the declaration of emergencies. The Secretary of Agriculture will have the authority to declare an emergency when a newly introduced noxious weed poses a significant threat, and to transfer money from other agencies or corporations of the Department (including the Commodity Credit Corporation) to cover the cost of eradicating the weed.

The PPA also clarifies the extent of the Secretary's authority to regulate biological control agents and encourages the USDA, other federal agencies, and the states to facilitate biological control of pests and other invasive species, whenever feasible. The Act also provides USDA with guidance on how to regulate the movement of biological control organisms, and authorizes USDA participation in activities that enable the effective transfer of biological control techniques. Other enhancements under the new law are: (1) harsher civil and criminal penalties for smuggling illegal plants, or products that could harbor plant pests, noxious weeds, or plant diseases; and (2) new authority to subpoena evidence and witnesses in the prosecution of violators.

Executive Order 13112

President Clinton signed Executive Order 13112 on Invasive Species (64 *Fed. Reg.* 6183, Feb. 8, 1999) on February 3, 1999, revoking President Carter's 1977 Executive Order 11987 on exotic species.[63] This Order seeks to prevent the

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[63] Although this Order is an attempt by the President to provide relief, such executive action might not provide a final remedy. Executive action is limited by the authority provided for in Article II of the Constitution, and no specific constitutional authority granted to the President permits such action. Similarly, no act of Congress empowers the President to take such executive action. Therefore, Executive Order 13112 could potentially be challenged (continued...)

introduction of invasive species, provide for their control, and minimize their impacts through better coordination of federal agency efforts under a National Invasive Species Management Plan to be developed by an interagency National Invasive Species Council (NISC). The NISC was directed to provide leadership, coordination, oversight of federal agency activities, to encourage work with non-federal partners, and to aid public participation. The Order directs all federal agencies to address invasive species concerns, as well as refrain from actions likely to increase invasive species problems.

The Secretaries of Agriculture, Commerce, and the Interior co-chair the Council. In addition, the membership of the Council consists of the Secretaries of Defense, Health and Human Services, State, Transportation, and Treasury as well as the Administrators of the Agency for International Development and EPA. Along with its many partners, the Council maintains a substantial website [http://www.invasivespecies.gov/] which contains the plan and provides extensive links to major data bases. There is a small staff, and the three lead Departments have appointed liaisons to the Council.

The Executive Order also requires an advisory committee on which a wide range of non-federal entities is represented. The advisory committee includes academics, representatives of state and local governments; port authorities; the pet, nursery, and pesticide industries; several environmental groups; a commercial fisherman; and a rancher. The committee is divided into several working groups, which are co-chaired by a member of the committee and a federal employee.

Some constituencies initially expressed concern about how the Executive Order might affect their interests. Although rural agricultural groups have long been involved in the control of invasive species, some elements of this constituency criticized the Executive Order as an attempt to rule by decree and as a threat to rural life and property.[64] However, a search of websites of groups which had expressed concern earlier suggests that by and large this concern is mentioned less frequently now than when the Order was first issued. The pet and nursery industries are another important constituency affected by the Order. Environmental groups have given minimal attention to the Order, but have expressed particular concern about the threat to biodiversity posed by non-native species.[65]

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[63] (...continued)
in the judiciary as a violation of the separation of powers. For more information on the legal status of Executive Orders, see CRS Report 95-772 A, *Executive Orders and Proclamations*.

[64] For an example of reaction from the property rights perspective on the perceived threat posed by the Order, see: [http://www.freerepublic.com/forum/a36c98bd20881.htm] and [http://www.libertymatters.org/new_page_53.htm].

[65] Web sites on non-native species (with or without coverage of the Executive Order) by environmental organizations include
[http://www.igc.org/wri/wri/wri/biodiv/gbf/gbf13-02.htm]
and [http://tncweeds.ucdavis.edu/].

Agency Responsibilities: Programs and Implementation

These entries describe how federal agencies address non-native species concerns. Most of these programs also address problems of native pest species or other domestic issues. No agency devotes a large percentage of its resources to non-native species issues. Even so, in some cases (*e.g.*, APHIS), non-native species account for a substantial portion of the workload; in others (*e.g.*, Coast Guard), non-native species are a minor share of the total program. Outside of some activities in the agricultural sector, no evidence was found of efforts in any agency to control the exports of U.S. species which could become harmful or invasive in the countries receiving them. The management plan of the National Invasive Species Council, while discussing improvements in international cooperation in general terms, does not describe any specific agency tasks which the United States itself might identify to prevent the spread of U.S. species that might cause harm in other countries.

Homeland Security and Invasive Species

Certain key agencies, including the Coast Guard and that portion of APHIS having to do with port inspection, are to be transferred to the new Department of Homeland Security. It is unclear how much emphasis the new department can be expected to place on interdiction or control of non-native species whose entry could be characterized as mistakes rather than attacks, and whose effects might be primarily economic or environmental rather than acutely dangerous to society. Even so, a case could be made that the same precautions designed to avoid bioterrorism could also reduce biological invasions whose origins are not terrorists. The focus on terrorism is too new to determine how it will affect invasive species problems.

Interagency Efforts

National Invasive Species Council. The NISC and its member agencies, supported by its advisory committee, was to develop recommendations for international cooperation, promote a network to document and monitor invasive species impacts, and encourage development of an information-sharing system on invasive species. The Council released the first national invasive species management plan (*Meeting the Invasive Species Challenge*) in January 2001, and recommended nine goals for invasive species management. With the help of the advisory committee, it also recommended research needs and measures to minimize the risk of species introductions.[66] The report constitutes the major federal attempt to date to coordinate invasive species actions over a broad range of species and habitats; across federal state, and local governments; and with private industry, interest groups, and private individuals. Some of the major features in the three key areas of prevention, early detection and rapid response, and control and management are given below.

[66] The plan is available at [http://www.invasivespecies.gov/council/nmp.shtml].

Prevention actions in the plan include:

- An effort to increase APHIS and FWS inspections at ports of entry, if resources permit.

- A division of actions into those required for prevention of (a) intentional actions which may prove harmful and (b) unintentional introductions.

- By December 2003, the development of a risk-based comprehensive screening system to evaluate first-time intentional introductions.

- By 2006, the development by federal agencies (with other interested parties) of a phased-in evaluation process for intentional introduction of (a) biological control agents for animal pests, (b) all non-native freshwater or terrestrial organisms to Hawaii and insular territories; and (c) non-native propagative plants, seeds, or land animals, or aquatic organisms, regardless of purpose, to the continental U.S.

- For unintentional introductions, further control of pests in ballast water and wood packing materials; identification of high risk non-native species requiring special prevention effort; education of U.S. travelers on the risks of returning with potential pests; and by 2003, development of a system to evaluate and rank pathways of potential introductions along with mechanisms to intervene and prevent them.

Early detection and rapid response actions in the plan include:

- Compiling a list of taxonomic experts, particularly where the need (risk) is greatest.

- Developing methods to detect pathogens and parasites that may affect the health of humans or any other species.

- Monitoring locations for likely introductions, *e.g.*, ports, highways, railroads, airports, construction sites, etc.

- Creating convenient systems to identify and report the presence of invasive species to federal, state, tribal, and local governments, as well as to share this and a variety of related information *via* the web to interested parties, including the public.

- By 2003, the establishment (by NISC and other federal government agencies) of a program to coordinate response to incipient invasions, including interagency response teams having members with a range of expertise.

- Testing detection and control methods to determine which are most appropriate for potential invasions.

- Proposing revisions of current policies and procedures (*e.g.*, for quarantines, pesticide applications, interagency jurisdictional questions, etc.) for compliance with current federal laws (*e.g.*, ESA, NEPA, Clean Water Act, etc.) as well as non-federal laws or regulations.

- For the FY2003 budget, developing and recommending to the President legislation for rapid responses to incipient invasions and possibly for permanent funding for rapid responses and for matching grants to develop state capacities. (This has not yet been achieved, although some legislation introduced in the 107th Congress would have addressed some of these issues; within existing authorities, NPS has already created emergency response teams for plant invasions, but is markedly limited in its ability to work on any but NPS lands; see discussion of NPS, below.)

Control and management actions in the plan include:

- Identifying and adopting sanitation methods to prevent the spread of invasives (*e.g.*, controlling the use of contaminated soils; requiring pest-free mulch, sod, and ballast water; and restricting the transfer of potentially contaminated fire-fighting or construction equipment).

- By January 2002, developing (by EPA) a proposal to cooperate further with private industry for the use of pesticides to control invasives, in a manner consistent with pesticide laws. (No such proposal has been published as yet.)

- By January 2002, developing and proposing draft legislation (by USDA) to the President to authorize matching funds for states to manage invasive species and to control invasives on state or private lands with the consent of the owner. (No such proposal has been published as yet.)

- By January 2003, NISC to issue guidelines for ranking invasive species control projects at local, regional, and ecosystem levels.

This plan is to be updated biennially to report on progress toward recommended goals and objectives. The Council is to assess the effectiveness of this Order at least once every 5 years, with a report to the Office of Management and Budget on whether the Order should be revised.

Efforts to control invasive species have been remarkably bipartisan, with little difference in approach between Republicans and Democrats, *per se*. While some have advocated more or less spending for invasive species problems, differences tend to be regional rather than partisan. Moreover, the transition between Administrations does not appear to have changed the approach of the NISC or the agencies described below in any readily discernable manner.

Aquatic Nuisance Species (ANS) Task Force. The ANS Task Force was established in 1991, and is an intergovernmental organization dedicated to implementing NANPCA by preventing and controlling aquatic nuisance species. The Task Force, co-chaired by FWS and NOAA, coordinates government efforts related to nonindigenous aquatic species in the United States with those of the private sector and other North American interests. The Task Force consists of seven federal agency representatives and 11 *ex officio* members. The other federal agencies are EPA, Coast Guard, Army Corps of Engineers, USDA, and Department of State. Four regional panels for the Great Lakes, the western region (17 western states), the Gulf Coast, and the northeast serve as regional advocates and advisory committees to the ANS Task Force to coordinate interagency efforts to address regional priorities. The ANS Task Force approves comprehensive state and interstate plans for managing nonindigenous aquatic species, permitting implementation efforts to receive federal funding. There are currently nine state/interstate plans that have been approved (see *State Efforts* below) and 11 states/tribes receive cost-share grants from the FWS to implement components of the plans. The Task Force recently initiated a public awareness campaign targeted toward aquatic recreation users entitled "Stop Aquatic Hitchhikers". The campaign builds on voluntary recreational activities guidelines to highlight measures that can be taken to minimize the spread of aquatic invasive species.[67]

Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW). This Committee was created through a memorandum of understanding among agency heads in August 1994.[68] It is composed of agency representatives from 16 federal agencies with invasive plant management and regulatory responsibilities, including: the Departments of Agriculture, the Interior, Transportation, Defense, and Energy as well as EPA. FICMNEW fosters cooperative work on integrated ecological approaches to management of noxious and exotic weeds on federal lands and provides technical assistance on private lands. Recent accomplishments include publication of a weed fact book, *Invasive Plants: Changing the Landscape of America*, as well as the document *Pulling Together: National Strategy for Invasive Plant Management*.

Department of Agriculture

The Department of Agriculture has a variety of programs affecting invasive species. Agencies of the Department, along with the Departments of Commerce and the Interior, are working to prepare a cross-cutting budget for invasive species spending in FY2004.

Agricultural Research Service (ARS). ARS provides scientific and technical support for USDA's regulatory agencies, including APHIS. In FY2002, APHIS transferred about $10 million of its appropriation to ARS for research on such things as detection technology for ports of entry, systematics for rapid identification

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[67] See [http://www.protectyourwaters.net/]; the ANS Task Force also manages a website at [http://anstaskforce.gov].

[68] FICMNEW manages a website at [http://ficmnew.fws.gov/].

of invading species, and pesticide application technology. In addition, ARS, under its FY2002 appropriation, is allocating $107.9 million to research on invasive species, and $119.8 million to research on integrated pest management (IPM) and biological controls for invasive pests and weeds, including helping to monitor target pests of IPM programs (*e.g.*, ground, aerial, and satellite monitoring of leafy spurge and other weed species).

Among ARS's recent research accomplishments on invasive species are:

- identification of a parasite that would destroy outbreaks of papaya mealybugs, an invasive species from the Caribbean which has recently become established in Florida;
- implementation of a 5-year research and demonstration program to reduce leafy spurge on rangeland using combined biological control and integrated grazing systems;
- investigation of a chemical attractant that could facilitate detection of the Asian longhorned beetle;
- development of the first biological control agent (a weevil) to eradicate the invasive *Melaleuca* tree;
- discovery that certain short-lived herbicides effectively control hydrilla and Eurasian watermilfoil in lakes, with little environmental impact.

Animal and Plant Health Inspection Service. APHIS is responsible for approximately 78% of total federal spending on invasive species in FY2002. (See Appendix B.) The agency conducts preclearance activities, treatment programs, detection surveys, and eradication efforts to prevent the introduction of specific foreign pests that would threaten U.S. agricultural production and natural ecosystems through an agriculture quarantine inspection program conducted at 178 U.S. ports of entry. These foreign pests include insects, plant and animal diseases, mollusks, mites, and invasive plants. Domestically, APHIS cooperates with federal and state agencies as well as non-governmental organizations to detect, contain, and eradicate infestations of selected foreign pests before they become well-established and spread. APHIS may use integrated management approaches including biological control to address widespread insects, diseases, and selected weeds that cannot otherwise be eradicated.[69] The majority of APHIS's relatively small budget for non-native species concerns is devoted to border control, with relatively little expended for treatment of infested sites.[70]

Under agency interpretations of NEPA, APHIS may approve and issue permits for importing nonindigenous species (7 CFR 372.5(b)(4)) following preparation of an environmental assessment rather than an environmental impact statement. Permits for importing nonindigenous species into containment facilities (7 CFR 372.5(c)(3)(iii)(A)) and for interstate movement of nonindigenous species between

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[69] The APHIS home page is [http://www.aphis.usda.gov/ppq/weeds/].

[70] For more information see [http://www.aphis.usda.gov/oa/invasive/invasive.html].

containment facilities (7 CFR 372.5(c)(3)(iii)(B)) are categorically excluded from the agency's NEPA requirements.

Within APHIS, Wildlife Services addresses a variety of problems related to wildlife damage of agriculture and other affected industries. While the targets of these control efforts commonly are native species such as coyotes, Canada geese, red-winged blackbirds, etc., non-native animals may be affected as well. If non-native animal populations reach levels that threaten aircraft takeoffs and landings, increase the spread of wildlife-borne diseases, harm threatened or endangered species, or threaten loss of life, habitat or food supply of other species, the Service may provide assistance. In general, its work focuses on target organisms after they reach problem levels, rather than immediate control after the initial discovery of a non-native.

Among the recent activities of APHIS regarding prevention and control of invasive species are:

- continued detection and delimitation (and an attempt at eventual elimination) of the Asian longhorned beetle, using $30 million in emergency funds;

- successful reductions of stands of Dalmatian toadflax, leafy spurge, and purple loosestrife using leaf-eating, stem-boring, or root-galling exotic insects that infest only the target species;

- cooperation with the U.N. Food and Agriculture Organization (FAO) and the Caribbean Community in a regional program to prevent the tropical bont tick, which could introduce heartwater and dermatophilosis diseases into wildlife and livestock populations, from entering the United States and its territories.

Cooperative State Research, Education, and Extension Service (CSREES). CSREES is the USDA agency that distributes federal funds to support research and extension programs at the land grant colleges of agriculture in every state. CSREES allocates some funds to each state according to formulas spelled out in authorizing laws, and distributes the rest through various competitive grant and earmarked grant programs. State-level research on invasive species, and extension programs to help farmers, ranchers, and other residents adopt cost-effective, environmentally safe controls for invasive species, are supported through one or more of these means.

Economic Research Service (ERS). ERS, the USDA's economic research agency, contributes to the Department's invasive species efforts through the pesticide use and pest management economic research and analysis program. This program provides information that is used to administer the integrated pest management program, Food Quality Protection Act implementation, and invasive species programs. The agency has not focused any research specifically on invasive species in 2001 and 2002. However, the Bush Administration's FY2003 budget request proposed a $2 million increase to support an ERS project that would examine the economic effects of invasive species on crops, livestock, commodity markets, trade,

and regional economies, and evaluate the benefits and costs of various approaches to preventing the introduction of, or eliminating, those species.

Farm Service Agency (FSA). In managing the Conservation Reserve Program, FSA requires all participants to control weeds (including noxious weeds), insects, pests, and other undesirable species on enrolled lands.

Forest Service (FS). The FS manages 192 million acres of federal lands for many values, including protection from invasive weeds. It also is the USDA agency that conducts the greatest amount of nuisance weed control. To support these efforts, the FS conducts research focused on invasive plant species, including ecological studies to support restoration of sites after treatment of exotic weeds, as well as control of: *Miconia* sp. and other invasive plants in Hawaii; kudzu in the southern United States; yellow starthistle, spotted knapweed, and leafy spurge in Idaho; and more. In addition, the FS seeks to control and mitigate the impacts from harmful non-native insects, such as the Asian longhorned beetle, gypsy moth, hemlock woolly adelgid, and browntail moth. The agency conducts research on such tree diseases as butternut canker and sudden oak death syndrome, and works to find and develop trees genetically resistant to Dutch elm disease, pitch canker, chestnut blight, and white pine blister rust. The FS works closely with state agencies, private landowners, and tribal governments on prevention and control activities, and provides funding and technical assistance through its state and private forestry programs.

The Administration's FY2003 budget request proposed an increase of $1.2 million for an emergency fund that could be used for rapid responses to new introductions of non-native or invasive pests or diseases for which no previous federal funding has been available.

Natural Resources Conservation Service (NRCS). NRCS provides technical assistance to cooperating landowners and federal agencies (such as the Forest Service and Bureau of Land Management) on adopting conservation practices on agricultural land, including rangeland. The agency operates 22 Plant Materials Centers that seek to use plants to solve conservation problems. The Centers are conducting 54 studies nationwide that strive to control or suppress weeds, and 146 studies focused on finding suitable replacements for invasive species once control is achieved. Some of the target weeds in this effort are yellow starthistle, cheatgrass, knapweed, Canada thistle, and cogongrass. The Plant Centers also promote the use of native species on the more than 30 million acres enrolled in the Conservation Reserve Program, a multi-year land retirement program.

Department of Commerce

The Department of Commerce has a variety of programs affecting invasive species. Agencies of the Department, along with the Departments of the Interior and Agriculture, are working to prepare a cross-cutting budget for invasive species spending in FY2004.

National Oceanic and Atmospheric Administration (NOAA). NOAA is the statutory co-chair of the interagency Aquatic Nuisance Species Task Force and has been delegated responsibility from the Department of Commerce to be the co-

chair of the National Invasive Species Council. Through both the Sea Grant program (see below) and a ballast water management technology development program, NOAA has funded research on alternatives to ballast water exchange as methods of ballast water management. NOAA line agencies, including the National Ocean Service and the National Marine Fisheries Service, have been involved in both prevention and control activities. The National Ocean Service has begun an effort to monitor coastal areas for the presence of nonindigenous species.

NOAA's Great Lakes Environmental Research Lab (GLERL) targets two components of the invasive species issue: (1) prevention and control to stop the inflow and spread of new aquatic organisms, with particular emphasis on ship ballast and (2) understanding and minimizing the ecological and economic impacts of recent species invasions, especially the on-going secondary effects of zebra mussels.[71] The lab's current research program reflects both priority areas: GLERL developed and provides leadership for the Great Lakes NOBOB (no-ballast-on-board) and Ballast Exchange research program (biological assessment of ballast tank residuals, experimental determination of effectiveness of ballast exchange) with combined funding from NOAA and several other agencies. In this program, GLERL scientists collaborate with scientists at several universities and the Smithsonian. In a related project, scientists at GLERL and the University of Michigan are evaluating two chemicals for use on residuals in NOBOB tanks. GLERL also leads investigations of invasive species impacts on the Great Lakes ecosystem, focusing on zebra mussels and other recent invaders. One project studies whether recent changes in the food web of the southern basin of Lake Michigan were caused by nonindigenous species. Another project examines the impacts on fish communities in the Great Lakes as a result of recent invasions. In FY2003 GLERL will start a new project to develop a model of ballast tank flow during ballast tank exchange.

National Sea Grant College Program. Sea Grant programs on invasive species focus on marine systems and the Great Lakes, through funding of research, education, and outreach to address threats from invasive species.[72] Specific research is supported on the biology and life history of non-native species; impacts of invasive species on ecosystems, including socioeconomic analysis of costs and benefits; control and mitigation options; prevention of new introductions; and reduction in the spread of established populations of harmful non-native species. Where success has been achieved in invasive species management efforts in coastal and Great Lakes states, Sea Grant programs have been critical. In addition, Sea Grant funded a 3 year Nationwide Zebra Mussel Training Initiative that allowed Sea Grant professionals to provide services outside the coastal and Great Lakes areas. This Initiative was instrumental in providing inland states with a knowledge base for creating state and regional programs.

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[71] See [http://www.glerl.noaa.gov/res/Programs/nsmain.html].

[72] The Sea Grant Program manages an Aquatic Nuisance Species Clearinghouse website at [http://www.aquaticinvaders.org/].

Department of Defense

The Department of Defense (DOD) engages in management and control of invasive non-native species. It is promulgating joint regulations with the Environmental Protection Agency covering discharges from DOD vessels. These regulations (40 CFR 1700) implement §312(n) of the Clean Water Act. When complete, they will set discharge standards for vessel ballast water to address the environmental effect of non-native species introduction *via* that ballast water (as well as addressing chemical pollution from other Armed Forces vessel discharges). The regulations are being developed in three phases. The first, completed in May 1999, determined which ballast-water discharges would require control. The second, currently in progress, will set performance standards, and the third will promulgate regulations for meeting those standards. The Armed Forces Pest Management Board coordinates DOD activities to prevent and control the spread of invasive species, including the brown tree snake and noxious weeds, on, to, or from military bases.

Army Corps of Engineers. The Army Corps of Engineers supports a range of invasive species efforts. The Aquatic Plant Control Program provides cost-shared (50%) assistance to states in managing aquatic plants in non-federal waters. The Environmental Research Laboratory administers an Aquatic Plant Control Research Program, which develops methods to assess and manage invasive aquatic plants. The laboratory also administers a zebra mussel research effort to develop control measures. The Corps fully funds control of aquatic plants, predominantly for invasive species, in waterways in certain southeastern states through the Removal of Aquatic Growth (RAG) Program. It is also conducting a Chicago Channel Dispersal Barrier Study to determine effective measures to limit the dispersal of harmful non-native species. The Corps also assists in the broader DOD initiatives described above.

Department of the Interior

The Department of the Interior (DOI) has a variety of programs affecting invasive species. Agencies of DOI, with the Departments of Commerce and Agriculture, are working to prepare a cross-cutting budget for invasive species spending in FY2004.

Bureau of Indian Affairs (BIA). The Bureau of Indian Affairs is responsible for protecting and improving the trust assets of Indian tribes while maintaining a relationship within the spirit of self-governance. The BIA, through exotic weed eradication and other programs, helps support the management of non-native species on Indian lands (*e.g.*, reservations, pueblos, rancherias, communities). Its Noxious Weed Control program is the focus of its efforts (see Appendix B for spending levels). The program provides matching grants to tribes for weed control in the BIA's 12 regions. It has no national program for harmful non-native animals, although some tribes work with the Forest Service for control of such insect pests as gypsy moths and other forest insect pests; funding for these programs comes through the Forest Service. Agency officials have not been major participants in the activities of the NISC.

Bureau of Land Management (BLM). BLM focuses its non-native species efforts primarily on controlling invasive plants, especially on the 264 million acres it manages, primarily in western states and Alaska.[73] BLM's action plan, Partners Against Weeds, details their strategy to prevent and control the spread of noxious weeds on public lands; the seven goals of the plan roughly parallel those of NISC. BLM instituted a Communication and Environmental Education Plan to help prevent and control the spread of noxious weeds on public lands, and adopted policies to address weed infestation. Current BLM studies address biological, chemical, and physical treatment protocols for invasive plants in the western United States. In addition, BLM has the somewhat conflicting role of protecting and managing wild horses and burros which, although not native, have a legally protected status. APHIS, through its Wildlife Services program, regulates animal pests (primarily predator control) on BLM land under a Memorandum of Understanding between APHIS and BLM.

On its grazing lands, BLM requires that non-native plant species be used only when native species are not available in sufficient quantities or are incapable of maintaining or achieving properly functioning conditions and biological health.

Bureau of Reclamation (BOR). The research, prevention, detection, and control programs of this agency address the pests of aquatic systems such as canals, reservoirs, pipelines, and rivers. Such species include both plants and animals, *e.g.*, hydrilla, Eurasian watermilfoil, zebra mussels, and Asian river clams. Their presence results in loss of irrigation water, impediments to navigation, and lost recreational opportunities. BOR works with other federal agencies, state and local governments, and others to control these pests. Methods include biological control agents and pesticide application. Projects include, among other things, insect biological control for five weed species; grass carp (itself a non-native species) for control of certain aquatic weeds, and use of herbicide meters to match herbicide flow to fluctuating water levels. The agency also maps the movement of certain invasive species (*e.g.*, populations of *Salvinia molesta* (an aquatic weed), hydrilla, and zebra mussels), and works with cooperators in Cooperative Weed Management Areas in western states to identify and control weeds. It works to improve control methods and basic knowledge of non-native species, and to develop methods to restore areas of salt cedar infestation. BOR works with Mexican officials on cross-border weed infestations.

Fish and Wildlife Service (FWS). FWS focuses its efforts on preventing the introduction and spread of invasive species and, where feasible and warranted, on controlling established non-native species. Its authority to protect domestic ecosystems is indirect or general, meaning the agency sometimes finds itself at odds with other interests, particularly those wishing to introduce various species for sport fishing or hunting. Its broad authority under the Endangered Species Act gives it some authority if a proposed introduction or other activity seems likely to harm a protected species. Its spending on harmful non-native species occurs in five of its programs: habitat conservation (coastal program), Partners for Fish and Wildlife

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[73] BLM's website is at [http://www.blm.gov/education/weed/weed.html/]. For the PAWs program, see [http://www.blm.gov/education/weed/paws/].

(including some funding earmarked by Congress for special projects), refuge operations and maintenance, fisheries (including the Aquatic Nuisance Species and brown tree snake programs), and international affairs.

In FY2003, FWS proposes to allocate $3.7 million nationally to control invasive plants and animals on the 93 million acre National Wildlife Refuge System (NWRS). Many refuges spend substantial portions of their budgets on the control of such non-native species as pigs, melaleuca, salt cedar, purple loosestrife, etc. The agency attempts to minimize the use of pesticides and herbicides in these efforts. A full-time national coordinator works with regional coordinators and refuge staff and government officials of other agencies and levels.

FWS is working with the USGS to survey the units of the National Wildlife Refuge System for more specific information about invasive species problems at all units. The data will be compiled into a central database called the National Biological Information Infrastructure (NBII; see USGS, below) to facilitate early detection and predictive modeling efforts for invasives in each Refuge.

Geological Survey (USGS). The Biological Resources Division of USGS focuses on researching factors influencing invasion by non-native species and the effects of invasive species on ecosystem processes, native species, and landscape dynamics, especially on Department of the Interior lands. Through the National Biological Information Infrastructure, USGS works to document, disseminate, and integrate information about the nation's biological resources generally, including its nonindigenous species.[74] USGS has focused on a small number of highly invasive species in the Great Lakes and eastern waterways and wetlands, in riparian ecosystems, and in Hawaii and Florida, as well as invasive plants on western rangelands. USGS also manages the national Nonindigenous Aquatic Species Database, as well as several regional databases (*e.g.*, Hawaii, Colorado plateau, and northern prairie) and manages a nonindigenous aquatic species website.[75]

National Park Service (NPS). Approximately 200 NPS units (*e.g.*, national parks, national monuments, preserves, national lakeshores and seashores, national scenic trails, national historic sites and parks, *et al.*) of the over 375 NPS units have identified, in their resource management plans, exotic species as a significant resource management concern. The NPS uses integrated pest management to manage exotic species. Fences are constructed to prevent exotic pigs, goats, and cattle from entering sensitive areas or spreading invasive species to parts of other parks. For example in Hawaii, NPS designates Special Ecological Areas that best represent Native Hawaiian systems, fences these areas, and then removes exotic species from them. Theodore Roosevelt National Park and Devils Tower National Monument are serving as insectaries where biocontrol agents are harvested and made available to surrounding landowners.

NPS has special regulations to minimize the potential for spreading zebra mussels and other aquatic nuisance species at the St. Croix (Wisconsin) National

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[74] Information on the project is found at [http://www.nbii.gov/about/index.html].

[75] The website is at [http://nas.er.usgs.gov].

Scenic Riverway (36 CFR 7.9), where *aquatic nuisance species* is defined as meaning the zebra mussel, purple loosestrife, and Eurasian water-milfoil. In the western United States, NPS finds leafy spurge and knapweed to be among the most problematical non-native species, while concern increases further west for Japanese brome (*Bromus japonica*) and cheat grass (*B. tectorum*).

NPS regulates fishing on its lands (36 CFR 2.3(d)(2)) and prohibits the possession or use of live or dead minnows or other bait fish, amphibians, non-preserved fish eggs or fish roe, as bait for fishing, except in designated waters. Waters which may be so designated are limited to those where non-native species are already established, where scientific data indicate that the introduction of additional numbers or types of non-native species would not hurt populations of native species, and where park management plans do not call for elimination of non-native species.

NPS Rapid Response Teams. In FY2001, NPS created Exotic Plant Management Teams for rapid response to invasive plants on units of the National Park System. The teams are explicitly modeled on teams used to fight fires. The current 9 teams may increase to 16, if funding permits. In their FY2001 report, the teams claimed elimination of two invasive plant species at Haleakala National Park and of all exotic plants at Loggerhead Key at Dry Tortugas National Park, among other accomplishments. Lake Mead National Recreation Area is serving as the focal point of an Exotic Plant Management Team whose tasks include controlling salt cedar. The team approach provides quick response and consistent application of techniques, provides a personnel resource not available to these parks, and reduces the need of individual parks to procure and maintain expensive equipment.[76]

In contrast to interagency fire suppression efforts, current law does not authorize these teams to be shared with other agencies for work on non-federal or other federal lands, although NPS teams do train personnel from other federal agencies with these methods. Despite this problem, the current nine NPS teams do work with many partners, ranging from National Wildlife Refuges, Florida Power and Light, and the Nature Conservancy to coordinate plant pest control and eradication efforts.

Office of Surface Mining Reclamation and Enforcement (OSM). OSM, in certain situations, allows the use of introduced species in revegetating reclamation sites (30 CFR 715.20(b), 717.20(b), 816.111(b)(5), and 817.111(b)(5)), directing that introduced species be substituted for native species only if appropriate field trials have demonstrated that the introduced species are equal or superior to natives for the approved post-mining land use, or are necessary to achieve a quick, temporary, and stabilizing cover. Such species substitution must be approved by OSM. Introduced species must meet applicable state and federal seed or introduced species statutes, and must not include poisonous or potentially toxic species. Western states have particularly attempted to avoid introducing invasive species on reclaimed minelands. Less attention has been given to the problem in the east,

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[76] For more on the teams, see [http://www.nature.nps.gov/epmt]. It appears that no similar teams function to control invasion of exotic animals, such as lake trout at Yellowstone Lake; animal invasions continue to be handled on an *ad hoc* basis.

although Kentucky has experienced serious problems with kudzu. For more information about OSM, see: [http://www.osmre.gov/].[77]

Department of State

The Department of State works with other federal agencies, states, tribes, non-governmental organizations and the private sector to develop U.S. foreign policy on invasive species, which it then seeks to integrate into international agreements such as the Convention on Biological Diversity.[78] The Department also is negotiating with the International Maritime Organization to develop a plan to control the spread of invasive species from exchange of ships' ballast water. The State Department's Bureau of Oceans and International Environmental and Scientific Affairs is striving to increase international awareness of invasive species through a series of regional workshops. The workshops aim to facilitate regional cooperation on strategies to address this cross-sectoral international problem.

Department of Transportation

Coast Guard. Under the Non-Indigenous Aquatic Nuisance Prevention and Control Act (NANPCA), the Coast Guard is responsible for developing and implementing a ballast water management (BWM) program to prevent the unintentional introduction and dispersal of nonindigenous aquatic species into waters of the United States from ship ballast water. This is presently accomplished through a mandatory BWM program for the Great Lakes ecosystem and voluntary guidelines for the remainder of U.S. waters. Relevant regulations are published at 33 CFR Part 151, Subparts C and D.

As stated in the Secretary of Transportation's June 2002 Report to Congress on the effectiveness of the voluntary BWM program, the Coast Guard plans to develop regulations requiring active BWM of all ships that enter U.S. waters after operating beyond the Exclusive Economic Zone, and will establish sanctions for failure to comply. The Coast Guard will also continue its efforts to establish a quantitative ballast water treatment (BWT) performance standard; protocols for testing, verifying and reporting on BWT technologies; and a program to facilitate experimental shipboard installation and operation of promising BWT technologies.

Federal Aviation Administration (FAA). FAA personnel, in coordination with APHIS, worked with Hawaiian transportation officials to develop a risk management plan for the Kahalui Airport, Maui, to minimize the potential for brown tree snakes and other invasive species to arrive *via* aircraft. Internationally, FAA (with support from APHIS) initiated efforts and prompted the International Civil Aviation Organization to pass a resolution encouraging pre-boarding education and

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[77] For more information about OSM, see [http://www.osmre.gov/]. This site provides information about OSM generally, and has some information about the agency's attempts to conserve native plants species. As of September 2002, there appeared to be no entries on strategies to avoid spreading invasive species *per se*.

[78] However, the United States is not a signatory to this treaty.

screening as well as other means to reduce the risk of introducing potentially invasive species by commercial aircraft.

Federal Highway Administration (FHwA). Direct activities by the FHwA focus primarily on research, guidelines, and conferences to help state transportation departments prevent and combat roadside invasive species. Vegetation management activities are state-funded and the FHwA does not participate directly in those activities.

Executive Office of the President

Council on Environmental Quality (CEQ). The Council on Environmental Quality assists in formulating agency guidance in integrating issues involving non-native invasive species in the process of implementing NEPA. CEQ coordinated and led the Clinton Administration's efforts on developing Executive Order 13112 on Invasive Species.

Office of Science and Technology Policy (OSTP). OSTP was involved in reviewing different issues and options as well as developing a white paper for the Clinton Administration's Executive Order 13112 on Invasive Species. The Committee on Environment and Natural Resources (CENR) of the President's National Science and Technology Council (NSTC), which is administered through OSTP, identified invasive species as a priority research focus and established an interagency Task Team on Invasive Species. Representatives from several federal agencies serve on CENR, including Defense, EPA, Interior, NOAA, NSF, USDA, the Smithsonian, State, Transportation, and the Council on Environmental Quality. E.O. 13112 specifically directs the National Invasive Species Council to work with CENR.

Office of the United States Trade Representative (USTR). USTR may play a limited consultative role in instances where invasive species concerns may arise in relation to international trade agreements.

Independent Agencies

Environmental Protection Agency. The Environmental Protection Agency (EPA) is a member of the National Invasive Species Council and actively participates in implementing the invasive species management plan. EPA conducts and supports research on the prevention, early detection, control, and management of invasive species. For example, Agency scientists are working with investigators at the University of Kansas to develop models to identify the potential niche for non-native species. Model results are used to estimate the area and spreading rates for potentially invasive species. These same models are being used to evaluate the impact of climate change on the invasiveness of non-native species. Additional efforts within EPA's Office of Research and Development (ORD) are focused on developing methodologies for the early detection of non-native invasive species and approaches for applying those methodologies in existing environmental monitoring programs. ORD investigators are also working with regional staff to develop

guidance for including evaluations of the potential impacts of invasive species in NEPA assessments.

In addition to these active research programs, EPA is involved internationally in cooperative efforts focusing on the early detection and rapid response to potential invasive species. These efforts are mainly coordinated from the Agency's regional offices surrounding the Great Lakes and regional offices in the Northeast and involve considerable collaboration and cooperation with Canadian environmental resource managers. As part of these international efforts, EPA is designing public awareness programs to educate stakeholders and the public about the risks and impacts of invasive species. Invasive species public awareness programs are also sponsored by various estuarine management groups who participate in the Agency's Office of Water, National Estuary Program (NEP).

National Science Foundation. The National Science Foundation funds basic and applied research on invasive species, including their roles in population and ecological processes, their relationship to biological conservation activities, and their role as a disturbance agent in ecosystems.

Smithsonian Institution. The Smithsonian Environmental Research Center (SERC) performs research on invasive species in coastal ecosystems. SERC collects and analyses data and reports on such species to determine patterns of transfer, invasion, and impact. Specific projects examine patterns of ballast-water delivery; test the susceptibility of marine communities to invasive species; document the history of alien species invasions for Chesapeake Bay; establish a national database on nonindigenous marine and estuarine species; measure ecological impacts; and measure species transfer associated with shipping. In cooperation with the Coast Guard, SERC established the National Ballast Water Information Clearinghouse to measure the changing patterns of ballast water delivery and management for vessels arriving in U.S. ports and to synthesize national data on patterns and impacts of alien species in coastal ecosystems. Aquatic and terrestrial invasive species research is also conducted by the Smithsonian Institution's National Zoological Park, the Smithsonian Tropical Research Institute, and the National Museum of Natural History.

State Efforts

This report focuses on federal programs and policies dealing with non-native species and does not discuss the extensive efforts of individual states to deal with these concerns. State efforts on this issue are highly variable. For examples of state programs addressing invasive species, see:

Virginia [http://www.dcr.state.va.us/dnh/invinfo.htm];
Michigan [http://www.michigan.gov/deq/0,1607,7-135-3313_3677_8314---,00.html];
Wisconsin [http://www.dnr.state.wi.us/org/caer/ce/invasives/];
Hawaii [http://www.state.hi.us/dlnr/Alien_Species.html];
Florida [http://www.dep.state.fl.us/lands/invaspec/]; and
California [http://endeavor.des.ucdavis.edu/weeds/].

For additional information on state and local programs addressing non-native species concerns, see p. 201-231 of the 1993 OTA Report *Harmful Non-Indigenous Species in the United States*.

Under the NANPCA, nine state/interstate aquatic nuisance species management plans to guide efforts had been completed and submitted to the federal government by mid-2002.[79] In addition, two state plans (Massachusetts and Wisconsin) have completed the public comment process and are nearly ready for submission by the state governors. An additional three states (Montana, Maine, and Alaska) have plans currently in the state public comment process. States in the earlier stages of developing plans include Idaho, California, Arizona, Texas, Louisiana, South Carolina, Hawaii, and Maryland. Despite substantial federal authorizations, relatively little has been appropriated or made available for grants to implement these state management programs.

International Efforts

Non-governmental organizations have been active in focusing international attention on the problems of non-native species introductions. In 1988, the European Inland Fisheries Advisory Commission (EIFAC) and the International Council for the Exploration of the Sea (ICES) published Codes of Practice and Manual of Procedures for Consideration of Introductions and Transfers of Marine and Freshwater Organisms, which subsequently was modified by ICES to include genetically modified organisms.[80]

In July 1991, the International Maritime Organization's (IMO's) Marine Environmental Protection Committee (MEPC) issued voluntary "International Guidelines for Preventing the Introduction of Unwanted Aquatic Organisms and Pathogens for Ships' Ballast Water and Sediment Discharges."[81] Adopted by a diplomatic conference of the IMO in 1993, IMO-member states were requested to follow these guidelines, which also called for exchange of ballast water in the open ocean (to reduce transfer of species from port to port). A review conducted by Australia in 1993 revealed that few countries had implemented the guidelines. In 1994, the MEPC established a ballast water working group to draft regulations for the control and management of ships' ballast water. These draft regulations were debated at the November 1998 and June 1999 MEPC meetings. Consideration will be given by the IMO to adopting these management protocols as a formal IMO

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[79] New York, Michigan, Ohio, St. Croix River (Minnesota and Wisconsin), Washington, Iowa, Illinois, Lake Champlain Basin (New York and Vermont), and Oregon. For details of these plans, see [http://www.anstaskforce.gov/mgtplans.htm].

[80] International Council for the Exploration of the Sea. *ICES Code of Practice on the Introductions and Transfers of Marine Organisms*. 1994. Copenhagen, Denmark. 5 p.

[81] [http://www.botany.hawaii.edu/bot350/1997/cullins/gcrab~1.htm]

instrument.[82] If adopted, the instrument would require all ratifying member nations to follow the regulations, which would include open-ocean exchange.

Several international agreements and codes of conduct address non-native species. For example, Article VI of the International Plant Protection Convention focuses on regulated pests, establishing an international system using inspections and quarantines to prevent the dissemination of pests affecting plants.[83] In 1995, the members of the Food and Agriculture Organization of the United Nations (FAO) adopted the Code of Conduct for Responsible Fisheries, which complements the Convention on Biological Diversity and contains several sections on the responsible use of non-native species in fisheries and aquaculture.[84] A key aspect of the Code of Conduct for Responsible Fisheries, as well as the Convention on Biological Diversity, is the adoption of a "precautionary principle"[85] to development. FAO and the Government of Sweden elaborated operational guidelines for this approach in relation to capture fisheries and species introductions.[86] Member States of FAO are now working to promote and implement these guidelines. To assist in the responsible use of aquatic introductions, FAO maintains an interactive website and database on introductions of aquatic species that contains an annotated registry of introductions that includes some of their ecological and social impact, the reason for the introduction, and who was responsible for the introduction.[87]

In 1996, the International Union for the Conservation of Nature (IUCN) developed and released the document *Draft IUCN Guidelines for the Prevention of*

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[82] As of the date of this report, it is uncertain whether the new instrument will be an Annex to the International Convention on Marine Pollution (MARPOL), a new convention, or a code of conduct. For additional details on these negotiations, see [http://globallast.imo.org/].

[83] [http://www.fao.org/ag/agp/agpp/pq/default.htm]

[84] [http://www.fao.org/fi/agreem/codecond/ficonde.asp]

[85] This principle, exemplified in the expression "better safe than sorry," can be loosely defined as applying to situations when potential harm is serious and irreversible, though full scientific certainty is lacking. In such instances, the precautionary principle would have regulators act to reduce (or eliminate) the harm while weighing the probable costs and benefits of acting or not acting. The precautionary principle is not the sole purview of one side of the debate, and if applied to more than one goal (*e.g.*, community stability and species preservation) may point to multiple and contradictory choices. For discussions of the precautionary principle, see Poul Herremoës, *et al.*, eds., *Late Lessons from Early Warnings: the Precautionary Principle 1896-2000*, European Environment Agency, Report No. 22; and Vern R. Walker, "Some Dangers of Taking Precautions Without Adopting the Precautionary Principle: A Critique of Food Safety Regulation in the United States," *Environmental Law Reporter*, v. 31 (2001): 10040-10047. A significant aspect of the debate on this issue, particularly in the regulation of pollution, is what level of knowledge is needed about potential harm to justify action.

[86] FAO. *Precautionary Approach to Fisheries. Part 1: Guidelines on the Precautionary Approach to Capture Fisheries and Species Introductions.* FAO Fish. Tech. Paper 350/1, (Rome, FAO: 1995).

[87] FAO Database on Introductions of Aquatic Species (DIAS) at [http://www.fao.org/fi/default.asp].

Biodiversity Loss Due to Biological Invasion. It focused on recommendations for reducing the risks of biodiversity loss caused by alien species, as envisioned under article 8(h) of the Convention on Biological Diversity (CBD).[88] In February 2000, the final guidelines document was published, making the loss of biological diversity caused by invasive alien species one of the central components of the CBD.[89]

A July 1996 Conference on Alien Species in Trondheim, Norway, sponsored by the United Nations Environment Programme, the Secretariat for the Convention on Biological Diversity (CDB), and the Scientific Committee on Problems of the Environment (of the International Council of Scientific Unions) provided an international forum for dialogue among scientists and policymakers on research and management issues related to alien species. Also in 1996, following concerns being expressed about the potential ecological harm of certain imported biological control agents, FAO published the "Code of Conduct for the Import and Release of Exotic Biological Control Agents."[90] This code was meant to introduce procedures to regulate imports of biocontrol agents so that benefits are achieved without harming health or the environment.

In June 1997, the United States submitted a document, *Trade in Alien Species*, for consideration at the Tenth Meeting of the Conference of the Parties to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to further increase international attention to the issue of invasive species.[91] In 1998, the FAO published international guidelines for pest eradication. [92] These guidelines for national plant protection organizations give directions on how to develop environmentally sound emergency eradication programs.

Finally in 2001, the Global Invasive Species Program (GISP)[93] signed a memorandum of cooperation with the Secretariat of the Convention for Biological Diversity (CDB) to assist in developing a pilot initiative on invasive species. The agreement requires that GISP act as an international focal point to disseminate information on invasive species to Convention Parties, to governments and to the general public. GISP and the CBD also will collaborate to develop invasive species programs.

Under the North American Free Trade Agreement, a Commission on Environmental Cooperation (CEC) plays a potentially important role in protecting

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[88] [http://www.iucn.org/themes/ssc/news/invasives.htm]. The United States is not a party to the Convention and its participation is limited to that of an observer state.

[89] [http://www.iucn.org/themes/ssc/pubs/policy/invasivesEng.htm]

[90] [http://www.spc.int/pps/IPPC%20ICPM%20ISPM/ISPMs/ispm3e.pdf]

[91] [http://www.state.gov/documents/organization/2361.pdf]

[92] [http://www.spc.int/pps/IPPC%20ICPM%20ISPM/ISPMs/ispm9e.pdf]

[93] The Global Invasive Species Program (GISP) is an independent and international organization whose mission is "to conserve biodiversity and to sustain human livelihoods by minimizing the spread and impact of invasive alien species." (See [http://jasper.stanford.edu/gisp].)

native biota. For example, Ontario withdrew permission for Lake Huron cage culture of exotic Arctic char after the CEC expressed concern. In addition, the CEC wrote to the United States and Canada in 1988 expressing concern for the potential spread of exotic ruffe, resulting in new ballast guidelines by Canada (1989) and regulations by the United States (under NANPCA in 1990).

Coverage of Laws or Policy: Actions and Approaches

Comprehensive legislation on the treatment of non-native species has never been enacted, and no single law provides coordination among federal agencies. In 1993, the Office of Technology Assessment found:

> The current Federal framework is a largely uncoordinated patchwork of laws, regulations, policies, and programs. Some focus on narrowly drawn problems. Many others peripherally address [nonindigenous species]. In general, present Federal efforts only partially match the problems at hand.[94]

In the intervening decade, NISC has taken substantial steps toward sharing more information across governments and with the public. It has also begun to coordinate actions of federal agencies, asking specific agencies to take the lead in developing policies within their existing legislative mandates. Through its 2001 report, *Meeting the Invasive Species Challenge*, it has also outlined a set of actions (some planned and a few completed) to address the bulk of existing problems. These actions include developing legislative proposals to fill gaps in current law. To date, legislative effort has involved an *ad hoc* focus on well-established problems: the clear invasion of a single species, a handful of specific pathways of introduction, or damage or risks to agriculture. If Congress should choose to regulate non-native species across a range of species, ecosystems, or pathways, Article I, Section 8 (clause 3) of the Constitution, with its broad authority to regulate interstate commerce, appears to give it the authority to do so.

Current laws do not clearly address (a) prevention of biological invasion across foreseeable pathways (besides ship ballast water); or (b) explicit direction on management during that critical period between the introduction (or intentional release) of new non-native species and when the species becomes established and focus must shift from prevention to control.[95] Many scientists assert that the period shortly after introduction offers one last chance to stop a new harmful non-native from becoming established. Moreover, there may be economic and ecological savings from early intervention. For example, the effort to capture a single snake that *might* be a brown tree snake newly arrived at an airport in Honolulu, even if it were to cost tens of thousands of dollars, could prevent the expenditure of millions of dollars annually to control the snake if it were to become established on Oahu, and millions more in damage or compensation for losses due to the snake. Congress could address these gaps either by explicitly delegating such authority to the President or by crafting legislation.

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[94] OTA Report, p. 163.

[95] The authors in the course of their research discovered very few instances (*e.g.*, smallpox, nutria in East Anglia, UK) of control measures on a well-established species leading to long-term eradication. For established species, eradication is extremely improbable. For very recent arrivals, it could be possible. In contrast, prevention (here including a reduction in the number of non-natives establishing breeding populations each year) is probably more feasible.

Under current approaches, species are selected for control primarily based on the record of damage they have already inflicted, rather than for preventing damage that may occur in the future. Since predicting which species may produce catastrophic effects is difficult (see *Predicting an Invasion*, above), some agencies have, or are moving to, a "pathways of invasion" approach, sometimes with the support or direction of specific legislation (*e.g.*, for ballast water exchange). There appear to be no current efforts to identify additional likely pathways of invasion, however. (See *Approaches to Regulation: Species-by-Species vs. Pathways*, below.) Also, little emphasis has been placed on preventing the export of native species from the United States to other countries where they are not native (see Box, p. 6), even though President Carter's 1977 Executive Order instructed federal agencies to use their existing authorities to do so.

President Clinton's Executive Order 13112 on invasive species (see description, above) was a step toward a more comprehensive approach. Ultimately, it could lead to greater agency attention to non-native species (its stated purpose) and to greater coordination among agencies.[96] However, coordination of current efforts alone means that, where current efforts have gaps due to lack of coverage by existing laws or agency jurisdiction, those gaps will remain. The 1999 Executive Order directed agencies to consider the impact of introduced species abroad, but it did not prohibit exports of species not native to the receiving country.

The Order also created the National Invasive Species Council. Subsequently, the NISC has brought about major improvements in information-sharing among federal agencies and with state, local, and private officials. Among other things, federal agencies, working with the NISC, have met to examine invasive species problems in light of their existing authorities, and sought to allocate their efforts to those areas (geographic and topical) that are not handled by other agencies.

Federal Agency Actions: A Patchwork

The NISC has become the federal focus for efforts to control and prevent non-native species affecting a broad range of industries or ecosystems. However, many of the shortages of personnel which hampered efforts to limit the entrance of and damage from non-native harmful species remain.

Some agencies have particularly focused on this problem: the agriculture-forestry sector is the clear focus of APHIS, and the Army Corps of Engineers has led the control of non-native aquatic plants. APHIS can regulate imports of plants or animals that are listed as agricultural threats to this country, but its authority to

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[96] History did not provide grounds for optimism that the new Order would be implemented effectively: the OTA Report noted (p. 166) that the 1977 order "in practice ... has been ignored by most Federal agencies. Moreover, the Fish and Wildlife Service has yet [15 years later] to implement the order in regulations although specifically directed to do so." Opposition to proposed FWS regulations came primarily from agriculture, zoos, game ranches, aquaculture, and the pet trade. A revised version was opposed strongly by the hobby fish industry. The OTA Report also notes that at that time no major industry supported the proposed FWS regulations. However, the early years of the NISC suggest that this pattern may have changed substantially.

regulate living plants or animals once they are admitted is more limited. Most significantly, it does not regulate the release of species into the wild once they have been admitted, unless the species is already designated a noxious weed or disease carrier. It can, for example, inspect imported emus or ostriches for the sake of protecting domestic poultry from foreign diseases. But after the markets for these birds crashed some years ago, and many were released by emu ranchers, APHIS did not have authority to control release of this non-native species.[97]

Neither does APHIS regulate the commercial sale of species that are already well-established. Purple loosestrife, Norway maple, and English ivy continue to be widely sold in commercial nurseries. Even though all are important pests, their sale does not violate federal law. (See discussion of purple loosestrife in the *Gallery* below, for example.) The sale of some of these plants is forbidden by some states, but the plant could be purchased legally in one state and then moved along with household effects to another, thereby obviating the protection of the second state's laws.[98] While these species spread naturally, their sale in nurseries offers new opportunities to introduce such species in entirely new areas where they are not currently found, even as expensive control efforts occur in other parts of their ranges.

The Army Corps of Engineers attempts to control noxious aquatic plant species (*e.g.*, hydrilla) and other impediments to inland navigation. Yet the Corps has no role in preventing or regulating the release of such pests in the first place. Hydrilla infestations in Florida and the Potomac River, for example, were very likely caused by aquarium hobbyists dumping fish tank contents. It is unclear whether the dumpers violated any state or federal laws, even though their acts have resulted in hundreds of millions of dollars of private and taxpayer costs. (See *Hydrilla*, below.) While the noxious aquatic plant program has been active in the past, it has been reduced somewhat in a shift in the balance from federal to greater local responsibilities for maintenance and operation costs.

In contrast, FWS does not have authority to provide general protection for the country's ecosystems, nor even to protect those species popular for hunters and anglers. It could not stop an African game fish, for instance, from being released in the bayous of Louisiana or the mountain streams of Wyoming on the presumption that it would unbalance local ecosystems if the fish were to spread. Only if FWS knew that the species might harm a species protected under ESA would it have clear authority to stop the importation and release. Similarly, if there were an effort to import a new grass to improve forage on National Grasslands, it is unclear whether FWS could prevent the release of the species on general ecological grounds. NMFS has even less regulatory authority, since its responsibilities for inland waters are limited, and largely confined to demonstrable effects on anadromous species

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[97] If they reach pest levels, the Wildlife Services program within APHIS can take steps to control pest populations.

[98] There is a parallel with the state waterfowl hunting laws in the early 20th Century. States with restrictive, conservation-oriented laws were literally out-gunned by states with more permissive laws when the waterfowl migrated through several states. Pressure from state governments (and their hunters) seeking to put all states on an equal footing in the burden of conservation was a significant factor leading to federal migratory bird hunting laws.

protected under ESA. Without clear federal legal authority to protect the nation's ecosystems (except in agriculture), the information sharing under NISC takes on even greater importance, since simply informing responsible parties of the risks of their proposed actions may be one of the few vehicles available to deter potentially damaging releases.

Interaction of State and Federal Programs

The NISC has begun to step into the role of coordinator for federal-state responses to non-native species.[99] At the same time, states do not appear to have a role in carrying out many of the federal laws to prevent the invasion of harmful non-native species. For instance, under the Alien Species Prevention and Enforcement Act, which makes it illegal to ship several categories of species through the U.S. mail, a state role seems improbable. Nonetheless, within some well-defined arenas, substantial cooperation does exist. Federal and state cooperation seems to be especially strong in control of invasive plants where they threaten agriculture or forestry. APHIS is the lead federal agency for this effort. The Forest Service takes the lead in working with state, local, and private organizations to control tree pests, and the Natural Resources Conservation Service (NRCS) works directly with private landowners to control invasive plants (native or non-native). Some of the cooperation on federal lands is carried out through National Public Lands Day, an event coordinated by the National Environmental Education and Training Foundation, a non-profit foundation chartered by Congress in 1990. Events in 2002 include removal of exotic grasses at Saguaro National Park (AZ), and exotic seaweed eradication (*Gracilaria salicornia*) off the coast of Waikiki (HI).

The information-sharing promoted through the NISC may help states to play a greater role by promoting broader awareness of the potential effects of such species (thereby limiting plans for deliberate introductions) or by providing states with new information about strategies to control pests within their borders. Federal agencies are also more aware of options and techniques to control pests that lie on both sides of federal boundaries. Some examples of such cooperation include sea lamprey control in the Great Lakes, and the NPS Exotic Plant Management Teams, which work closely with neighboring landowners.

Approaches to Regulation: Species-by-Species *vs.* Pathways

Under a single species approach, plants or animals must be placed on a black list before they are regulated as harmful. Black list approaches to invasive species are, of necessity, done on a species-by-species basis. Harm can rarely be demonstrated unless the plant or animal is already at pest levels and inflicting damage somewhere, *i.e.*, generally after the species is reproducing and spreading. Usually, damage must be readily apparent before protection can begin, at which point prevention could be nearly impossible. Several examples of this approach are extant in law: coverage of the brown tree snake under NANPCA (which otherwise regulates the pathway of ship ballast water), and the requirement that individual weed species

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[99] However, a good deal of information on aquatic nuisance species was already collected by the ANS Task Force which preceded the NISC.

be placed on an exclusion list before they can be regulated under the Plant Protection Act.

There are a few instances of regulation and prevention by pathway. Among the most comprehensive has been NANPCA, as amended by NISA. Its focus is on ballast water as a risk to saltwater and freshwater ports, bays, and estuaries. Its goals put prevention on an equal or higher footing with control of species that are already established. It requires the participation of several federal agencies, promotes research, and implements regulations on the mid-ocean exchange of ballast water and various other measures to prevent non-natives from entering U.S. ports. Similarly, APHIS inspects imported agricultural products for pests. Pathway approaches also exist at the state level. Minnesota, for example, prohibits the transport of nearly all aquatic plants (native or non-native) and of zebra mussels on public roads. Depending on the particular offense, fines range from $50 to $500.[100] Pathway approaches do not require lists of organisms to be implemented or effective, and may even block the entry of species whose very existence is unknown to science.

A Few Legislative or Policy Options

Specialists in this field suggest that the following areas are either not addressed in current law, or might be explored by policymakers[101]:

- *Research to identify pathways and to improve control methods*. A pathways approach, to ensure that pathways are clean of living stowaways (regardless of whatever policy regarding black or white lists may be adopted for intentional introductions), could have some advantages. Stowaways, *per se*, have no supporters; opposition to preventive action would probably be based on practical considerations of cost, efficacy, safety, intrusion on otherwise legal goals, etc. However, with the exception of agricultural threats, there have been few comprehensive reviews to identify pathways providing the greatest risk of harmful non-natives. This research could be especially relevant to preventing unintentional introductions. The research goals would overlap strongly with research to prevent certain kinds of terrorist threats, and might benefit from cooperation with agencies involved in anti-terrorism programs.

- *Education campaign*. After a disastrous human-caused fire in New Mexico, a young black bear cub survivor was named "Smokey" by the Forest Service, and became in only a few years the nucleus of a highly successful educational campaign to reduce similar fires. A "Smokey Bear" equivalent for non-native species — an educational campaign, aimed in part at children – to prevent simple, inadvertent

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[100] Personal communication with Jay Randall, Coordinator, Exotic Species Program, Minnesota Division of Fish and Wildlife, on May 17 and July 14, 1999.

[101] Congress is considering many issues related to invasive species. The list of options below focuses only on topics which cover a broad range of species, pathways, or agencies.

acts by the public might play a significant role in preventing some types of non-native species introductions.[102] Preventing releases of exotic pets and aquarium species after the point of sale might be particularly susceptible to this approach.

- *Warning list*. While the current "black list" approach requires significant regulatory hurdles before a species can be included, an informational *warning list* (or "grey list") of species might be created by the collaboration of federal and state agencies. The warning list might include species currently restricted under state laws, species thought to be newly arrived from other countries, and other species felt to merit special attention by regulators.[103] Although it would lack regulatory force, the list could be designed to provide information on species whose eradication or control is in its early phases. Unification of data and reporting from many agencies would add greatly to the utility of such a list.

- *Review of industries dependent on importing and transferring non-native species*. Such a review, including a focus on cooperative methods to reduce introductions or releases after the point of sale, could be in order. The focus of past efforts has tended to be on the point at which these species enter the United States. To protect their businesses, import-dependent industries have naturally tried to reduce current obstacles and prevent imposition of new ones. In this effort, the pet trade (including the hobby aquarium and nursery industries) has been relatively successful. Yet this pathway offers other avenues to reduce risk besides prohibition. These avenues might include incentives for the sale of sterile animals or plants only or efforts to create point of sale educational programs to inform purchasers about the risk of releasing pets or plants into the wild and penalties for doing so. The Wild Bird Act (see above) could provide a model for legislation to encourage "homegrown" (if not native) species over additional foreign imports.

- *Multi-agency federal center for "first strike" prevention and control*. Since the creation of the NISC, agencies have begun to respond across a broad front in the days, weeks, or months after an invasion is discovered. The prompt notification and agency

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[102] While Smokey Bear has become widely recognized, other such efforts have been less successful. For example, the Forest Service's other symbol, Woodsey Owl, has been far less effective in reducing pollution and littering. In the early 1960s, USDA attempted to create "Pestina" to help educate the traveling public to the perils of non-native species imports. There was little effort to evaluate effectiveness, and little work with private and other federal agencies. The program was eventually dropped. (OTA Report, p. 142.)

[103] Appendix III of the Convention on International Trade in Endangered Species could provide a model for this type of approach. A nation may list any species native to it under this Appendix; through that listing, it requests the assistance of other member nations in controlling imports of that species when they arrive from the host nation.

attention to the discovery of northern snakeheads in Maryland is an example of such a response. (See *Snakeheads*, below.) However, while constraints on time, budgets, coordination, and jurisdiction interfere with prompt responses far less than in the past, further progress is possible. NISC is moving toward the model of a federal program which has long faced similar issues: interagency fire management.[104] It seems possible that a similar, multi-agency federal center devoted to "first strike" prevention and control of harmful non-native species, regardless of affected industry, ecosystem, or lead agency could be helpful. With a variety of expertise and resources, it could provide critical support at a time when eradication might still be possible. Another federal agency which plays a somewhat similar role is the Centers for Disease Control and Prevention, which conducts research and provides a degree of coordination for efforts to protect human health.[105]

In recent years, one agency (NPS), has adopted roughly this approach, within their budget constraints. Initially two teams were available to address invasive plant problems, not only in crises, but also for ongoing problems. While the teams (soon to number 16) can work only on NPS lands, they do work with adjoining landowners to control cross-boundary problems. Expansion of this program, perhaps with multi-agency teams, could provide a more efficient method of addressing new or incipient invasions. It seems unlikely, however, that each federal agency would need to create its own separate team modeled after those of NPS, since the duplication of effort would be substantial.

- *Expert review of planned releases*. Panels of experts might be created to review and make recommendations on releases by governments at any level, or by non-governmental sources into any environment in which the species are not native. According to the NISC,[106] steps along these lines are planned, and in the case of plants which may affect agriculture, are in progress. While such a panel could not have sounded the alarm on the unauthorized release of hydrilla into the Potomac, for instance, it could provide a public warning on a planned release of exotic grasses by federal agencies or of a non-native game fish species into a new drainage. The use of the expertise of federal and other scientists and managers, if it prevented even a few ill-advised introductions, might be a cost-effective option.

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[104] These issues are addressed by a federally coordinated National Interagency Fire Center, primarily under the management of the Bureau of Land Management. All federal land managing agencies participate, and a great deal of the program focuses on work with tribal, state, and local governments to bring many resources to bear on major fires.

[105] For more on the National Interagency Fire Center, see [http://www.nifc.gov/]. For more on the Centers for Disease Prevention and Control, see [http://www.cdc.gov/].

[106] *Meeting the Invasive Species Challenge*, p. 32-33.

- *Measures to reduce the risk of exporting invasive species*. Even in the absence of a treaty, the United States might wish to take internal steps to prevent exporting potentially invasive species to other countries. These measures could be as simple as restricting their use in bilateral aid programs or certifying that identified U.S. products (*e.g.*, used tires) are free of pests. This certification, for example, is done for agricultural shipments, but other areas or programs may be at risk of transporting non-natives as well. The management plan of the NISC considers international cooperation generally (p. 41-42) and describes actions which might be taken on a multilateral or bilateral basis to reduce the transport of invasive species. However, it does not address steps the United States might take unilaterally, nor assess any positive or negative results on U.S. trade that might occur from such steps. It is difficult to discern progress in this area in the last few years.

- *Convening an international conference*. To prevent further economic damage and enlist international cooperation, Congress might consider urging the President to seek an international conference to develop a treaty or other international agreements concerning this issue. Certification of the pest-free status of plant or animal specimens, pallet wood, or air cargo holds, or the adoption of other measures, might reduce the number of species entering this country, as well as prevent threatened trade wars if steps are taken unilaterally in the face of a new pest. Such protocols might have been helpful in U.S.-China discussions over the Asian longhorned beetle, for example.

A Gallery of Harmful Non-Native Plants and Animals

Below is a discussion of selected harmful non-native species, with emphasis on their economic impacts (where known), the affected industries or interests, the origin of the species, its pathway into this country, and its effects on natural ecosystems. Species are selected on the basis of past congressional interest, amount of economic damage, availability of information, and ability to illustrate the range of problems associated with introductions of non-natives. (Beneficial non-natives are not included; some species are included that are native to some regions of the United States but have become invasive in areas where they are not native.) Comparatively recent arrivals are emphasized over long-term non-natives. Most are well-established, but a few are not. Species are grouped by taxonomic affinities: microorganisms, plants, insects, other arthropods, mollusks, and vertebrates.

Microorganisms

Whirling Disease, *Myxobolus cerebralis*. Whirling disease is a protozoan parasite that affects the nervous system of trout species. This parasite must pass through two hosts in its life cycle — fish and a common aquatic worm. A free-swimming stage enters young trout where it attacks their cartilage. This parasite was first introduced to the United States from Europe in the 1950s, probably in infected trout. The disease spread as these infected trout were distributed among hatcheries or were stocked in open waters. According to information obtained by querying the database for the National Wild Fish Health Survey [http://wildfishsurvey.fws.gov/] on November 13, 2002, this disease has been detected in rainbow trout in at least 32 states and now occurs in wild rainbow trout in at least 23 of these states. (In the remaining states, this disease is believed to be confined to fish hatcheries.) While whirling disease is not a major problem in eastern states, it is severe in some western states, and has ravaged trout populations. To date, severe damage has been primarily to wild rainbow trout, although other salmonid species can become infected. Although several states are spending tens of millions of dollars annually to control whirling disease, no national or international cost estimates were found for damage caused by this species. In the 104th Congress, Sen. Baucus introduced S.1019, to direct FWS to examine the impacts of whirling disease, and other parasites and pathogens, on trout in the Madison River, and similar natural habitats. No action was taken on this measure, and no additional bills specifically addressing whirling disease have been introduced since the 104th Congress. Beginning in FY1997, federal funding specifically for combating whirling disease has been provided in the Department of the Interior appropriations for FWS. For more information, see:
[http://www.montana.edu/wwwrc/docs/whirling/centerpage/whirling.html];
[http://www.lsc.nbs.gov/fhl/fdl/17-lite.htm]; and [http://www.whirling-disease.org/].

Plants

All of the plants described in this report are covered in the comprehensive FICMNEW report (cited above). It analyzes 20 major invasive plant species, as well as their effects on different habitat types. Substantial information, particularly on the history of the plant invasions cited below, was drawn from the FICMNEW report.

Leafy Spurge, *Euphorbia esula*. This aggressive invader, native to Eurasia, was brought to this country in 1827 (and again at several later dates), possibly in contaminated seed. It is now found throughout the contiguous United States, except in the southeast. In open areas of pasture or rangeland, it crowds out other vegetation, and at concentrations above 10-20% cattle will not graze in infested land because of the irritating nature of the chemicals contained in the plant. The federal role has included USDA research on biological and chemical control methods and estimates of economic impacts. Biological control is being used in many areas, and USDA has shown success using several natural enemies of leafy spurge imported from Europe. States have their own major control programs, some funded by a cost-sharing program among states, local governments, and landowners. Direct and indirect economic effects of this species alone are estimated at hundreds of millions of dollars.[107] According to USDA, damage costs ranchers an estimated $35-45 million per year.

Purple Loosestrife, *Lythrum salicaria*. This wetland invader was imported from Europe in the early 1800s for its medicinal value, and for the beautiful purple spikes of the blooming plant. Unsuspecting visitors to an infested wetland often admire the beauty of the marsh when *L. salicaria* is in bloom, unaware that it has crowded out native plants and animals. This species is still sold as an ornamental in nurseries in some states, though many states have listed it as a noxious weed and prohibit its sale. According to FWS, purple loosestrife now occurs in every state except Florida. The plant is virtually impossible to eradicate, and its vegetative dominance may increase the likelihood of listing additional native species as threatened or endangered. One mature plant is capable of producing 2.7 million seeds in one season. Intensive chemical and mechanical control measures to reduce stands have been used for some time. Emerging biological control approaches show promise for improved control in the future, according to scientists. Estimated economic impacts are $45 million per year in forage losses and control costs.[108]

Spotted, Diffuse, and Russian Knapweed, *Centaurea maculosa*, *C. diffusa*, *Acroptilum repens*, and Yellow Starthistle, *Centaurea solstitialis*. The knapweeds were introduced from Eurasia as contaminants of alfalfa and clover seed, and one or the other of them is present in every state but Alaska. They are particularly problematic on rangelands in the western United States, because they are highly unpalatable to livestock and deleterious to wildlife habitat. According to reports, in Montana alone it is estimated that knapweed infestations cost $42 million in livestock productivity losses and control costs.

The yellow starthistle, a native of southeastern Europe, was introduced in the early 1850s apparently as a contaminant in alfalfa seed from South America. The flowers have stiff spines that can injure humans or livestock; they may grow in such dense stands as to prevent foot travel. The weed is also poisonous to horses. It is found in much of the west, primarily in rangelands but also in alfalfa and cereal grain croplands, orchards, vineyards, roadsides, and recreational lands. It is still spread *via* contaminated seed and it appears that recreational vehicles are a newer means of

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[107] FICMNEW, p. 26-28.

[108] Pimentel, *et al.*

transport. The species is most common in California, where it infests an estimated 10-15 million acres; and in Idaho it infests well over 1 million acres. Economic impacts are unknown, but native vegetation is crowded out where the plant is common. Treatment consists of application of herbicides to infested areas.

Melaleuca, *Melaleuca quinquenervia*. This Australian tree was introduced in the early 1900s as an ornamental. It is established in Florida, Louisiana, Hawaii and Puerto Rico, and is virtually at epidemic levels in Florida. In Florida, it was originally used as a windbreak and soil stabilizer, but it is also a heavy water user. In 1936, a private individual wishing to drain the Everglades spread seeds *via* airplane through southern Florida. It has had a major influence on water management throughout the area. It has a camphor-like odor, and its flowers and young leaves can cause skin and respiratory reactions in some people. Destruction of native vegetation, *e.g.*, by hurricanes, opens up further areas for Melaleuca infestations. Its spread is complicating efforts to restore the Everglades and improve water supplies in the economically growing area.

Water Hyacinth, *Eichhornia crassipes*. This freshwater aquatic plant originally came from South America, and forms impenetrable mats of floating vegetation (as much as 200 tons per acre). It was believed to have been introduced to the United States at the World's Industrial and Cotton Centennial Exposition in Louisiana in 1884-1885, after which a Florida visitor returned home and released the plant into the St. Johns River, east of Orlando. Currently its range includes Hawaii, California and most southern states, but scattered sightings have been reported as far north as Cape Cod. Water hyacinths clog flood-control and irrigation systems, provide habitat for disease-carrying insects such as mosquitoes, and prevent boats from moving on waterways. They also drastically reduce the diversity of native aquatic species, lower dissolved oxygen levels in the water so that fish die, accelerate the rate at which bodies of water fill in with silt, and prevent fish from spawning by covering spawning beds. U.S. annual expenditures to control aquatic weeds (most of them non-natives, such as water hyacinth) are reported to be $100 million.[109] For more information, see [http://aquat1.ifas.ufl.edu/hyacin2.html] and [http://www.invasivespecies.gov/profiles/waterhyacinth.shtml].

Salt Cedar, *Tamarix* (several species). Salt cedar species are spreading shrubs or small trees native to Eurasia, and were introduced as an ornamental plant in the United States by nurserymen in the 1830s. Salt cedar is now established in many moist spots in the desert regions of western states. It is an aggressive colonizer that is able to survive in a wide variety of habitats, and often forms monotypic stands, replacing willows, cottonwoods and other native riparian vegetation. Seedlings establish most frequently in soils that are seasonally saturated at the surface. It appears to grow best in saline soils (up to 15,000 parts per million sodium), but salt cedar is adaptable and tolerant of a wide variety of environmental conditions (Brotherson and Field 1987).

Hydrilla, *Hydrilla verticillata*. This freshwater aquatic plant originally came from Asia and has become the most abundant aquatic plant in Florida, where it grows

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[109] OTA Report, p. 67.

in thick surface mats and displaces native vegetation. This plant was imported into the United States in the early 1950s for use in aquariums, and was likely discarded into the wild near Tampa and Miami. A subsequent introduction occurred in the Potomac River basin. Distribution in the United States now ranges from Connecticut southward along coastal states to Texas as well as on the west coast in California and Washington. Several inland states — Pennsylvania, Tennessee, and Arizona — also have populations in some lakes. Generally, this species is most likely to spread when plant fragments are carried along with recreational boats into new habitat.

Hydrilla causes major problems with water use. In drainage canals, it greatly reduces flow, which can result in flooding and damage to canal banks and structures. In irrigation canals, it impedes flow and clogs intakes of irrigation pumps. In utility cooling reservoirs, it disrupts flow necessary for adequate water cooling. Hydrilla can interfere with recreational and commercial vessel navigation. In addition to interfering with boating by fisherman and water skiers, hydrilla hampers swimming, displaces native vegetation communities, and can damage sport fish populations. The economic losses in these water use values to property owners, tourists, and users can be staggering. U.S. annual expenditures to control aquatic weeds (most of them non-natives, such as hydrilla) are reported to be $100 million.[110] In the 99th Congress, P.L. 99-662 included a provision directing the Secretary of the Army to study the feasibility of eradicating and controlling hydrilla in the Potomac River. For more information, see
[http://aquat1.ifas.ufl.edu/hydcirc.html] and
[http://plants.ifas.ufl.edu/seagrant/hydver2.html].

Cordgrass, *Spartina* sp.. Although native to the eastern United States, this plant is considered an invasive marine weed in Washington, Oregon, and California. It was accidentally introduced to the Pacific Northwest more than 100 years ago, probably as packing material around oysters that were seeded there. *Spartina* radically alters native Pacific intertidal ecosystems, including the food webs, from mudflats to high marsh. This alteration affects the Pacific Coast's ecologically and commercially important native species. In 1995, the Washington Legislature declared the spread of *Spartina* to be "an environmental disaster." The Washington state government, local agencies, tribes, and non-profit organizations reportedly spend millions of dollars annually on efforts to eradicate cordgrass. For more information, see
[http://anrcs.ucdavis.edu/RadioNews/2000/1127/cut07.html] and
[http://www.efn.org/~ipmpa/Noxspart.html].

Caulerpa, *Caulerpa taxifolia*. Native to tropical oceans, *Caulerpa taxifolia* escaped in 1984 from a public aquarium in Monaco and subsequently spread to cover more than 6,000 hectares of the northwestern Mediterranean Sea, seriously reducing biodiversity in this area. The algae form a dense, uniform carpet that persists from year to year, and grow well in many diverse habitats. It is toxic and inedible to fish and marine invertebrates; it spreads unrestrained, covering and then eliminating many plant and animal species. The 1999 discovery of *Caulerpa* on the Californian coast near San Diego raised public concern about the potential danger of a new invasion

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[110] OTA Report, p. 67.

similar to the one in the Mediterranean. Substantial efforts are being expended to eliminate the California invasion.[111] For more information, see [http://swr.nmfs.noaa.gov/hcd/caulerad.htm] and [http://www.swrcb.ca.gov/rwqcb9/News/Caulerpa_taxifolia/Fact_sheet_11-01-01.pdf].

Arthropods: Insects

Formosan Termite, *Coptotermes formosanus*. The Formosan subterranean termite is native to China and east Asia. It is known to have spread to Sri Lanka, South Africa, Hawaii and the southeastern United States. Its spread probably began with the return of various tankers and cargo ships after World War II; returning cargo probably rested on or in infested packing material and pallets. The major threat posed by this species went unrecognized for more than 20 years, although a few scientists tried to sound the alarm.[112] The species now exists from California to Florida and north to Virginia, with ideal habitat being found particularly in the more humid Gulf Coast area. The species does not exist where winters are more severe. In very dry areas a source of water, such as a leaky pipe, is essential for their survival. Spread of the colonies appears to be primarily by human transport of infested wood or soil. (The winged queens and kings are very weak fliers.)

The termites are extremely destructive and colonies eventually have millions of workers and soldier termites. Severely infested structures will collapse — a stage that is reached more quickly with this species than with domestic species of termites. When living trees are infested, treatment is extremely difficult, since pesticides on the surface of the tree have very little effect on the termites inside. Destruction of trees in New Orleans is severe, leaving some streets virtually bare. Damage from the species, plus the cost of treating infected buildings and trees, is estimated in the hundreds of millions of dollars annually in New Orleans alone, and about $1 billion nationwide.[113]

The widespread distribution of this species combined with the severe difficulty in controlling it means that its major limiting factor may be its relative intolerance for lower temperatures and lower humidity. Even so, central heating and dense construction may allow a limited invasion into heated buildings in colder states. The current focus of the federal government is on treatment and methods of control, more than on the prevention of new imports of a species that is already widely distributed. Currently, research into control and detection methods is being conducted by USDA's Agricultural Research Service, whose program is described at [http://www.ars.usda.gov/is/fullstop/].

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[111] Jay Withgott, "California Tries to Rub Out the Monster of the Lagoon," *Science*, v. 295 (March 22, 2002): 2201-2202.

[112] One of these scientists, Jeffery LaFage, an entomologist from Louisiana State University, had just begun an effort to support treatment in the historic French Quarter of New Orleans when he died in 1988. The French Quarter is now probably the most highly infested area of the Gulf, due to the favorable climate and the architecture of the area.

[113] Agricultural Research Service at [http://www.ars.usda.gov/is/fullstop/faqhome.htm].

Imported Fire Ants, *Solenopsis invicta* and *S. richteri*. Fire ants first entered the United States from Argentina through the port of Mobile, Alabama, perhaps as early as 1918. Since then up to five different species, including the red and the black imported fire ants, have spread through much of the southeast, reportedly as far north as Maryland, and west into Southern California. These species develop very large surface-dwelling colonies in disturbed areas such as pastures and lawns. The sting of an individual ant is usually severe, and the colony's habit of swarming quickly up the leg of any animal that slows briefly near a nest has earned the species a ferocious reputation. In severe cases or among sensitive individuals, some (human, cattle, and other species) have died from the stings; even rainbow trout have been killed.[114] Some agricultural areas are severely hampered with high levels of infestation. In residential areas, people complain of being unable to use their yards, or allow their pets outside. Estimated damage to livestock, wildlife, and public health in Texas alone are $300 million annually, and $2 billion per year nationally.[115] In the 105th Congress, Sen. Gramm introduced S.932 to establish a National Advisory and Implementation Board on Imported Fire Ant Control, Management, and Eradication to provide grants for research or demonstration projects related to the control, management, and possible eradication of imported fire ants; the bill was not acted on.

An unrelated ant species, the **little red fire ant** (*Wasmannia auropunctata*), was found in Hawaii in 1999. This tiny reddish invader, a native of tropical America and from south Florida, is a common inhabitant in orange and coffee groves, and is noted for its painful and long-lasting sting.

Argentine Ant, *Linepithema humile*. Argentine ants (until recently called *Iridomyrmex humilis*) have been present in the United States for about a century. These ants are common household pests in most parts of the country, including Hawaii. Their sting is negligible except to unusually sensitive persons. The ants can enter very small openings to take food from all but the most tightly sealed containers. They can be serious garden and orchard pests due to their habit of guarding aphids and certain other plant pests and feeding off of the honeydew produced by these insects. The guarded pests thereby reach population levels much more likely to damage the host plants. In optimum habitats, colonies of Argentine ants can reach 300,000 ants in colonies with multiple queens capable of laying thousands of eggs per day. They out-compete most other native ant species for food sources. Even that other major ant invader, the fire ant, may find itself starved out of an area due to the efficiency of the Argentine ant. In turn, populations of lizards, frogs, and other organisms that feed on native ants may plummet.

Economic effects fall primarily on horticultural species and commercial crops, from oleander to oranges. Homeowners are affected as well. To the extent that the Argentine ant reduces populations of animals (*e.g.*, through competition) or plants

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[114] "Fire ants to blame for deaths of trout," by Thaddeus Herrick. *Houston Chronicle*. June 11, 1998. The trout had attempted to ingest winged queen and male ants that had fallen into a stream; it is unclear whether the fish were stung by the queen ants (males do not sting) or whether the toxins in the ants poisoned them.

[115] "Deadly southern fire ants are on the move," *USA Today*, Dec. 15, 1998, p. 15A.

(*e.g.*, through displacing a plant species' closely adapted pollinators or allowing plant pests to increase), the species could cause some species to be listed under the Endangered Species Act, thereby increasing regulatory burdens on affected parties. For more information, see
[http://www.hear.org/hnis/index.html#LinHumI01].

Africanized Honeybee, *Apis mellifera scutellata*. This subspecies of honeybee is an extremely close relative of the European honeybee, familiar to beekeepers around the country.[116] Neither subspecies is native to North America but the European honeybee is one of the arrivals to North America whose benefits in crop pollination are thought to outweigh the detrimental impact on population levels of native bee species.[117] The sting of both subspecies is equal in severity, and worker bees of both species die as the result of stinging. Africanized bees are far more likely to attack, and attack in greater force, than their calmer European sisters. This reduced threshold for aggression poses dangers for humans, pets, domestic animals, etc., who may wander unknowingly past a hive, and for commercial beekeepers who find it far more difficult to manage their hives, and to move them to commercial orchards for pollination services.

After an accidental escape from research colonies in Brazil in 1957, the subspecies spread north and reached the U.S. border about 10 years ago. In the southern United States, a few very serious attacks (including at least four human deaths) have occurred. Current control efforts have fallen heavily on the beekeeping industry, which has had to supply new European queens to maintain the stability of working colonies. The economic impact has been an added blow to beekeepers (and therefore orchardists) suffering from other serious pests such as bee mites (described below). In a touch of environmental justice, however, these same bee mites attack Africanized bees as well as European bees, and the mites may be one reason why Africanized bees (unprotected in the wild by human keepers) are expanding their U.S. range somewhat more slowly than expected. The increased costs of control measures could affect the cost of pollination services, reduce the number of beekeepers, and ultimately increase food costs for the crops (from alfalfa to oranges) that require pollination by bees.

Asian Longhorned Beetle, *Anoplophora glabripennis*. The Asian longhorned beetle has done much in recent years to increase awareness at the highest

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[116] The name "killer bee" has been abandoned by most experts because of the hysteria and panic it induces. Instead, "Africanized bee" is now accepted by entomologists as a name with a more neutral emphasis on both its geographic origin and successful adaptation to local conditions. In Europe, honeybees have been kept for millennia; in the process, beekeepers naturally selected for unusual gentleness. Bee colonies have not been kept in Africa until relatively recently, and natural selection favored those wild colonies able to defend themselves most aggressively from attack, leading to a more aggressive subspecies than European bees.

[117] Most native North American bees (*e.g.*, carpenter bees and sweat bees) are solitary, and many play an important role in pollination of wild plants and some crops (*e.g.*, squashes, watermelons, and cantaloupes). Where honeybee populations are high, competition can reduce populations of native bees; where mites have reduced populations of honey bees, native bees are increasing.

levels of government of the threats posed by the introduction of non-native species. This species has been reported in New York state and the area around Chicago. It appears to have arrived in packing materials or pallet wood from China, but the beetle is also native to Japan and Korea. It is considered an important threat to trees in its native range, and an even more serious threat elsewhere. In China, it attacks elms, poplars, and willows, among other species. In this country, it attacks a broad range of species, including willow, poplar, birch, rose of Sharon, horsechestnut, most maple (*Acer*) species (red, sugar, silver, box elder, and sycamore maples, as well as the introduced Norway maple), and many others. The species spreads slowly, and may infest a tree for years before the weakened tree dies. Because the larvae live deep within the tree, treating the living tree by spraying pesticides on its bark is usually ineffective. Cutting infested trees or treating them with systemic insecticides (*i.e.*, injected into living wood) are currently the only practical treatments.

In response to the threat posed by these beetles, APHIS issued an emergency regulation (7 CFR 319.40) prohibiting imports of untreated solid wood packing material from China. The regulation became effective Dec. 17, 1998. It requires solid wood packing material from China to be treated in any of several specified methods (including fumigation with methyl bromide) to kill this and other pests, and requires shipments from China to pay an inspection fee to cover the costs of these services. Other countries in eastern Asia also harbor this beetle, but were not included under the regulation. These regulations will reduce the chance of importing other species of pests from China that may inhabit solid wood. Since treatment will increase costs to export Chinese products to the United States, China objected to the regulation and threatened a trade war. Environmentalists also objected to the inclusion of fumigation with methyl bromide (a contributor to atmospheric ozone depletion) as an acceptable treatment option. Many observers cite this controversy as contributing to much greater attention at higher levels of government to problems created by the proliferation of non-native species. (For more information see [http://www.aphis.usda.gov/ppq/ep/longhorn/index.html].

In August 2001, a closely related species, the **citrus longhorned beetle (*Anoplophora chinensis*)**, was detected in a tree nursery in King County, Washington. According to USDA, the beetles were introduced inside bonsai trees from Korea, and some adult beetles were seen escaping into the environment. Like the Asian longhorned beetle, this species can attack a variety of hardwoods, including citrus trees. Washington state has placed a plant quarantine on all properties around the nursery, and has ordered the destruction of over 1,000 trees. At present, it is not known if the pest has become established. Another relative, the **white-spotted citrus longhorned beetle** (***Anoplophora malasiaca*)**, was intercepted in Wisconsin in 1999 in bonsai maples from Asia. No further reports on the status of this pest are available.

Asian Tiger Mosquito, *Aedes albopictus*. This mosquito is thought to have arrived to Houston, Texas, in 1985, in tires imported from Asia for re-treading. Its larvae are able to survive in almost any amount of standing water, from backyard dog dishes to cemetery flower pots. Unlike most mosquitoes, this one is diurnal, making it more likely than other mosquitoes to bite (largely diurnal) humans. The species can carry West Nile fever, encephalitis, dengue hemorrhagic fever, yellow fever, and several other important diseases. The tiger mosquito may also be able to

transmit canine heartworm. The Centers for Disease Control and Prevention (CDC) initially was concerned that the species could spread epidemics, but to date, no major epidemics have occurred. This prolific breeder has reportedly made some areas of the south-central and Gulf Coast states very unpleasant when its populations reach their highest densities.

Economic impacts have included higher costs for mosquito control programs in humid areas. Its possible medical threat is a more complex question. Its apparent failure to spread diseases so far has probably resulted from the complex biological interaction of the viruses, the mosquitoes, and the hosts. The insect's broad range of meal sources reduces the probability of transmitting most diseases: if it picks up yellow fever, for example, it will not transmit it to a human if its next meal is mouse blood. And a female mosquito may bite only a handful of times in her short adult life. In another odd twist, it may be that the larvae of this mosquito are out-competing the larvae of an introduced closely-related and dangerous cousin, *Aedes aegypti*, a very efficient transmitter of yellow fever. The CDC, responding to the public health threat, took steps to require the disinfection of imported tires. No disinfection of exported tires is required. As a public health matter, this disparity is unfortunate, since difficult sanitation conditions and reduced health care make the transmission of disease by this species far more likely in other countries than in the United States.

Mediterranean Fruit fly, *Ceratitis capitata*. The Mediterranean fruit fly, or medfly, is one of the world's most feared plant pests because the species has a wide range of host plants, and its larvae destroy many kinds of fruit and vegetables. Medflies attack over 260 host fruits and vegetables, and their maggot-like larvae destroy fruits or vegetables before becoming flies themselves, and beginning the process again. The species originated in sub-Saharan Africa but has spread to several countries in Europe and Central America. Medfly is not currently known to be established anywhere in the continental United States. The first known U.S. mainland infestation occurred in Florida in 1929, with several infestations since, especially in that state and in California. All these infestations were eradicated with the use of pesticide sprays, and more recently with the use of sterile males.[118] Unfortunately, medflies have been present in Hawaii since 1910, and all eradication efforts over the decades there have been unsuccessful.

Detection of medflies by U.S. or foreign plant health quarantine authorities generally results in an automatic ban of all fruit and vegetable trade from that country. For example, live medfly larvae were recently found in 'clementine' oranges from Spain in North Carolina, California, Louisiana and Maryland. In response, the Secretary of Agriculture immediately banned clementine shipments from Spain. These severe production and trade implications are the main reason why USDA maintains extensive fruit fly monitoring and eradication programs in several states and territories.

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[118] USDA maintains medfly rearing facilities abroad which produce sterile males for shipment to the United States as needed. Upon detection of a medfly hotspot in the United States, millions of these sterile flies are flown in from these facilities and released.

Other Arthropods

Honeybee Mites, *Acarapis woodi* and *Varroa jacobsoni*. The honeybee, itself a non-native species, has been threatened not only by its Africanized relative (see above), but also by two invading bee parasites. These mites (not insects, but tiny eight-legged relatives of spiders) are the tracheal mite (*A. woodi*) and the varroa mite (*V. jacobsoni*) from Europe and Asia, respectively. Tracheal mites clog the air passages of adult honeybees, eventually suffocating them. Varroa mites suck blood from adult and juvenile honeybees. Adults can be weakened to the point of death, and juveniles emerge deformed from their cells. Moderate infestations reduce pollination services and honey production, and eventually kill colonies. Costs of keeping bees escalate, increasing crop production costs and food prices.[119] Hobby beekeepers are virtually eliminated, as are wild populations of honeybees. The spread of these two kinds of mites may be playing a role in slowing the spread of Africanized bees farther from the Mexican border, since they too are susceptible to these mites. Populations of native bees (mostly solitary species such as carpenter bees, sweat bees, leaf-cutter bees, and others, plus some social species such as bumble bees) are increasing as the mites decrease the number of honeybees (of whatever subspecies) competing for available pollen.

Commercial orchardists have relied on movable commercial beehives, to have their crop and eat it too: while bees are present and working the crop, no pesticides are used, but when pollination is finished, commercial hives are easily removed, and crops can be sprayed to protect them from insect pests, blights, etc. Consequently, while the home gardener may be able to rely on increasing populations of native bees to take up the slack if wild honeybee colonies are declining, this option is more difficult for commercial growers. USDA researchers are seeking to control these mites in a number of ways: resistant strains of honeybees from areas where these parasites originated, changes in hive management, use of special foods to create greasy bees that are unattractive to mites, and chemical methods. Congressional issues have included primarily funding for research on control methods. For more information about varroa mites and tracheal mites, see [http://sun.ars-grin.gov/ars/Beltsville/barc/psi/brl/mite-vj.htm], and [http://sun.ars-grin.gov/ars/Beltsville/barc/psi/brl/mite-aw.htm], respectively.

European Green Crab, *Carcinus maenas*. This species was introduced to the U.S. Atlantic Coast from Europe's North and Baltic Seas more than 150 years ago. Around 1989, this very aggressive crab was introduced into San Francisco Bay where it feeds on bivalve mollusks and competes with native shore crabs. The European green crab also has a reputation for consuming large numbers of juvenile clams and oysters. On the Pacific Coast, it is extending its range northwards — mature adults have been caught as far north as the west coast of Vancouver Island,

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[119] Although crops pollinated by honeybees are valued at about $10 billion annually, pollination services represent only a very small fraction of the cost of producing most crops. Shortages of hives will have to become severe to have substantial effects in supermarkets. In the meantime, the beekeeping industry itself suffers most.

British Columbia. The annual estimated economic damage to shellfish production of the European green crab is about $44 million.[120] For more information, see:
[http://www.wa.gov/wdfw/fish/ans/greencrab.htm],
[http://www.pac.dfo-mpo.gc.ca/ops/fm/shellfish/Green_Crab/default.HTML], and
[http://www.sciencenews.org/sn_arc98/6_13_98/fob2.htm].

Chinese Mitten Crab, *Eriocheir sinensis*. This native of mainland China and coastal areas along the Yellow Sea was first collected in South San Francisco Bay by a shrimper during the winter of 1993. Although mitten crabs had previously been found elsewhere in the United States, San Francisco Bay was the first place where this crab could feasibly reproduce and increase its numbers. This crab spends 90% of its life in freshwater, migrating to saltwater to reproduce and die. Mitten crabs are omnivorous, with juveniles eating mainly vegetation. Some are concerned that burrows excavated by these crabs could accelerate bank erosion and cause levee damage in the Sacramento River delta. Although this crab is known to be the intermediate host of the Oriental lung fluke that can cause often fatal, tuberculosis-like symptoms in humans who consume these crabs raw or poorly cooked, this parasite has, thus far, not been found in the United States. At the height of their fall migration to saltwater in 1998, as many as 30,000 downstream-migrating adult mitten crabs clogged the fish salvage and trash screens at the Tracy (CA) irrigation pumps every day. The California Department of Fish and Game has rejected a petition to allow a test commercial fishery for these crabs, which are illegal to possess or transport live under current state law. While some are concerned that crabs could be intentionally transplanted to other rivers in an attempt to create a fishery, others believe a properly managed mitten crab fishery could be an economically viable way to help control this species. Meanwhile, a closely related Japanese mitten crab (*E. japonica*) has been found in the Columbia River Basin. For more information, see:
[http://www.wsg.washington.edu/outreach/mas/nis/mittencrab.html]
[http://www.sfbaymsi.org/mcrab.htm], and
[http://www2.delta.dfg.ca.gov/mittencrab/index.html].

Rusty Crayfish, *Orconectes rusticus*. This native to streams in the Ohio, Kentucky, and Tennessee region has been spread widely into adjacent states by anglers who use them as bait. Rusty crayfish are prolific and can severely reduce lake and stream vegetation, depriving native fish and their prey of cover and food, and reducing food for fish and waterfowl used to dining on smaller native crayfish. The decline of native crayfish species could harm entire aquatic ecosystems, since native crawfish are a favorite meal of bass, sunfish, and other predators. These predators are also important sport fish. It is unclear, however, whether these predators could substitute rusty crayfish for native crayfish species. For more information, see
[http://www.great-lakes.net/envt/flora-fauna/invasive/rusty.html],
[http://www.seagrant.umn.edu/exotics/rusty.html], and
[http://nas.er.usgs.gov/crustaceans/maps/or_rusticus.gif].

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[120] K.D. Lafferty and A.M. Kuris. "Biological Control of Marine Pests." *Ecology*, v. 77, no. 7 (1996): 1989-2000.

Spiny Water Flea, *Bythotrephes cederstroemi*. This native of Great Britain and northern Europe (east to the Caspian Sea) was first found in Lake Huron in 1984, probably imported in the ballast water of a transoceanic freighter. Currently, the animal can be found throughout the Great Lakes and in some inland lakes where it competes with young perch and other small fish for food. This species is easily spread when eggs and adults are transported in bilge water, bait buckets, and livewells. Also, fishing lines and downriggers can become coated with both eggs and adults. For more information, see
[http://www.great-lakes.net/envt/flora-fauna/invasive/spinyflea.html] and
[http://www.sg.ohio-state.edu/publications/nuisances/bythotrephes/fs-049.html].

Mollusks

Zebra Mussel, *Dreissena polymorpha*. In the late-1980s, zebra mussels were discovered in Lake St. Clair, between Lake Huron and Lake Erie, having arrived from eastern Europe via ballast water discharge from European freighters. This species spread rapidly to 20 states and as far as the mouth of the Mississippi River. Although early estimates of U.S. expenditures to control zebra mussels and clean water intake pipes, water filtration equipment, and electric generating plants and other damage were $3.1 billion over 10 years, recent reports suggest these 10-year costs were more likely between $750 million and $1 billion. In addition, others are concerned about potential damage to Pacific salmon freshwater spawning habitat if zebra mussels spread to Pacific Coast drainages. The 100th Meridian Initiative, a cooperative effort between state, provincial, and federal agencies, seeks to prevent the westward spread of zebra mussels and other aquatic nuisance species in North America. On the other hand, filter-feeding by this mussel has greatly improved water clarity in the Great Lakes. For more information, see
CRS Report 90-116 ENR, The European Zebra Mussel, *Dreissena polymorpha*,
[http://nas.er.usgs.gov/zebra.mussel/],
[http://www.wes.army.mil/el/zebra/zmis/zmishelp.htm], and
[http://www.great-lakes.net/envt/flora-fauna/invasive/zebra.html].

Brown Mussel, *Perna perna*. A native of Brazil, Venezuela, and South Africa, this species was introduced into the coastal waters of Texas in 1989, where it has spread from the mouth of the Colorado River[121] to Veracruz, Mexico. This species likely arrived in ballast water of a vessel from Latin America. The brown mussel is a biofouler (*i.e.*, it attaches to exposed solid surfaces) and is therefore likely to clog water and power plant intakes, similar to the zebra mussel. However, only limited damage has been reported thus far along the Gulf Coast. For more information, see
[http://twri.tamu.edu/twripubs/NewWaves/v12n3/abstract-3.html],
[http://www.mdsg.umd.edu/seagrantmediacenter/news/txmussels.html], and
[http://www.gsmfc.org/nis/nis/Perna_perna.html].

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[121] The west has two major rivers called "colorado" ("reddish" in Spanish). This one flows from west central Texas to the Gulf Coast, southwest of Galveston.

Asian River Clam, *Corbicula fluminea*. This clam has a huge natural range from temperate and tropical southern Asia west to the east coast of Africa, plus the eastern Mediterranean, plus southeast Asian islands south into central and eastern Australia. This species was introduced into the United States in 1938 as a food item used by Chinese immigrants. Since its first collection along the banks of the Columbia River near Knappton, Washington, it has spread into major waterways of 38 states and the District of Columbia by a combination of bait bucket introductions, accidental introductions associated with imported aquaculture species, and intentional introductions by people who buy them as food. This species' most prominent effect has been biofouling, especially of complex power plant and industrial water systems, but also of irrigation canals, pipes, and drinking water supplies. It alters the bottoms of streams and lakes, thereby damaging habitat for a number of species, and competes with native species for limited resources. Estimated annual damage is about $1 billion.[122] For more information, see [http://nas.er.usgs.gov/mollusks/docs/co_flumi.html] and [http://www.sgnis.org/publicat/nespp_4.htm].

New Zealand Mud Snail, *Potamopyrgus antipodarum*. A native of New Zealand, but long established in Australia and Europe, this species was discovered in North America in 1987 in Idaho's Snake River. Between Shoshone Falls and the C.J. Strike Dam, population levels may exceed 100,000 snails per square meter. This species was discovered in Lake Ontario in 1991, has also been found in Montana's Madison River, and most recently was detected in the Colorado River drainage. Ballast water transfer is the suspected source of this species. However, birds and sport anglers may also be spreading this pest to additional drainages. Although no effects on native species have yet been observed, scientists are concerned about competition with native mollusks for resources and habitat because of the mud snail's high reproductive rate. For more information, see [http://www.fcsc.usgs.gov/Nonindigenous_Species/New_Zealand_Mudsnail/new_zealand_mudsnail.html] and [http://www.protectyourwaters.net/hitchhikers/mollusks_new_zealand_mudsnail.php].

Vertebrates

Sea Lamprey, *Petromyzon marinus*. This species is generally marine but ascends freshwater rivers to spawn along the Atlantic Coast from Labrador to the Gulf of Mexico. This species was first reported in Lake Ontario in 1835, in Lake Erie in 1921, in Lake Michigan in 1936, in Lake Huron in 1937, and in Lake Superior in 1946. The sea lamprey may have entered Lake Ontario from its native habitat in the Atlantic drainage by migrating through the Erie Canal after the canal was opened between 1819 and 1825 or by hitching rides on boats passing through the Erie or St. Lawrence canal systems. Later, it entered the upper Great Lakes through the Welland Canal around Niagra Falls. Adult lampreys attack and parasitically feed on other fishes such as lake trout, often resulting in death of the prey, either directly from the loss of fluids and tissues or indirectly from secondary infection of the wound.

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[122] N. C. Balcom. *Aquatic Immigrants of the Northeast*, No. 4: *Asian Clam, Corbicula fluminea*." (Groton, CT: Connecticut Sea Grant College Program, 1994).

Progressively over the last 150 years, the sea lamprey caused the extinction of three species of endemic ciscoes (whitefish) in the Great Lakes, and drove lake trout and several other species to near extinction. Both recreational and commercial fisheries suffered major economic loss, with additional indirect losses in tourism and supporting businesses. Congress regularly considers the impacts of sea lamprey during debate on annual appropriations for the Great Lakes Fishery Commission for the U.S. share of sea lamprey control expenses with Canada (Department of State appropriations for "International Fishery Commissions"). The annual cost of international control programs for sea lamprey in the Great Lakes drainage is approximately $10 million to $15 million. For more information, see
[http://www.glfc.org/lampcon.asp] and
[http://nas.er.usgs.gov/fishes/accounts/petromyz/pe_marin.html].

Alewife, *Alosa pseudoharengus*. The alewife may have been native to Lake Ontario or could have reached the lake in the mid-1800s. Subsequently, this fish has spread through the Great Lakes via the Welland Canal, with first reports from Lake Erie in 1931, Lake Huron in 1933, Lake Michigan in 1949, and Lake Superior in 1954. The species was intentionally stocked in other inland waters. The disappearance of native plankton-eating fish, such as whitefish, in the Great Lakes has been attributed in part to the introduction of alewives, which reduce zooplankton populations. Some attribute the extinction of the lake herring and the decline of chub species in the Great Lakes to the alewife. Today, the alewife is the dominant fish in Lake Michigan, where it accounts for 70-90% of the fish weight (biomass). Pacific salmonids were introduced to the Great Lakes in the mid-1960s, in part as an attempt, albeit unsuccessful, to control the alewife populations. Alewives have damaged sport and commercial fisheries in the Great Lakes by eliminating certain species such as lake herring and emerald shiner, and have damaged tourism by undergoing periodic large-scale die-offs that litter beaches with rotting fish, posing both a nuisance and a health hazard. Costs of cleaning beaches have declined in recent years with reduced populations of alewives. For more information, see:
[http://nas.er.usgs.gov/fishes/accounts/clupeida/al_pseud.html] and
[http://www.invasivespecies.gov/profiles/alewife.shtml].

Round Goby, *Neogobius melanostomus*. Native to Eurasia including the Black Sea, Caspian Sea, and Sea of Azov and their tributaries, the round goby was first discovered in Michigan's St. Clair River in 1990. This fish species probably arrived in freighter ballast water. The species appears to be undergoing a population explosion in Lakes Erie, Huron, and Michigan. The round goby was first observed in Lake Superior in 1995. The round goby is aggressive, feeding voraciously upon small bottom-dwelling fishes (*e.g.*, sculpins, darters, and logperch), snails, mussels and aquatic insects. Abundance of native fish species has declined in areas where this goby has become abundant, with sculpins particularly affected. Thus, there is concern that the round goby may harm sport and commercial fisheries in the Great Lakes as well as indirectly affect tourism. The Army Corps of Engineers has constructed an underwater electric barrier in the Chicago Sanitary and Ship Canal in an attempt to prevent the round goby and other species from moving between the Great Lakes and the Mississippi River drainage. For more information, see
[http://nas.er.usgs.gov/fishes/accounts/gobiidae/ne_melan.html] and
[http://www.great-lakes.net/envt/flora-fauna/invasive/goby.html].

European Ruffe, *Gymnocephalus cernuus*. This fish is native to Northern Europe and Asia. The ruffe was first observed in 1986 in the St. Louis River along the border between Minnesota and Wisconsin. It has since spread into Duluth Harbor in Lake Superior and several tributaries of the lake. By 1994, the ruffe had spread eastward along the Lake Superior shoreline as far as Michigan's Ontonogan River, and was observed in Lake Huron in 1995. The ruffe was probably introduced from ship ballast water as early as 1982-1983. Ruffe have the potential to compete with native fishes, such as yellow perch, and could consume large quantities of eggs of commercially important lake whitefish and similar species. Thus, the major effect of this species may be on sport and commercial fisheries as well as indirectly on tourism. For more information, see:
[http://nas.er.usgs.gov/fishes/accounts/percidae/gy_cernu.html],
[http://www.fw.umn.edu/research/ruffe/], and
[http://www.great-lakes.net/envt/flora-fauna/invasive/ruffe.html].

Common Carp, *Cyprinus carpio*. Native to Asia, this species dispersed naturally into the Danube River where it gave rise to fish that the Romans moved around their Empire.[123] From Europe, this fish was introduced into the United States as a sport fish in the 1850s. Carp are currently found in every state except Alaska. Carp are bottom-feeders, destroying aquatic plants and increasing suspended sediments as they feed. Overabundant carp can severely deplete lake bottom food sources needed by species sought by sport anglers, such as yellow perch, bluegills, and channel catfish. Although carp are sought by some recreational anglers, most view carp as damaging sport fisheries for a variety of native species. For more information, see:
[http://www.und.nodak.edu/org/ndwild/carp.html] and
[http://nas.er.usgs.gov/fishes/accounts/cyprinid/cy_carpi.html].

Walking Catfish, *Clarias batrachus*. Walking catfish were imported to Florida, reportedly from Thailand, in the early 1960s for the aquarium industry. The first introductions apparently occurred in the mid-1960s when adult fish imported as brood stock escaped in Broward County. Additional introductions in Florida, apparently purposeful releases, were made by fish farmers in the Tampa Bay area in 1967-1968, after the state banned the importation and possession of this species. The species can migrate overland at night or during rain, which has allowed it to spread to 20 counties in southern Florida. Although aquarium releases are apparently responsible for subsequent discoveries in California, Nevada, Georgia, Massachusetts, and Connecticut, this species is not believed to have become established outside Florida. In Florida, walking catfish have invaded fish farms, where they enter culture ponds and prey on fish. However, no studies are known to have measured the ecological or economic impacts of this species. For more information, see [http://nas.er.usgs.gov/fishes/accounts/clariida/cl_batra.html] and [http://www.scotcat.com/factsheets/clarias_batrachus.htm].

Snakeheads, *Channidae*. This freshwater fish from tropical Africa and southern Asia has recently become a concern in the United States. Because this fish

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[123] Eugene K. Balon. *Domestication of the carp, Cyprinus carpio L.* Misc. Pub., (Toronto: Royal Ontario Museum, Life Sciences Div., 1974) 37 p.

can tolerate low oxygen conditions and is capable of overland migration by wriggling movement, it can spread to and occupy a variety of habitats. All life stages of snakeheads are highly competitive predators, with adults feeding on many species, including other fish, crustaceans, frogs, small reptiles, and sometimes birds and mammals. In the United States, four species of snakeheads have been recorded in the wild in seven states (California, Florida, Hawaii, Maine, Maryland, Massachusetts, and Rhode Island), and two of these species have established reproducing populations in Hawaii and Florida. Between 1997 and 2000, more than 15,000 live snakeheads were imported into the United States. On July 26, 2002, FWS proposed amending 50 CFR 16.13 to add snakeheads to the list of injurious fish, mollusks, and crustaceans, thus prohibiting their interstate transportation and importation into the United States.[124] For more information, see
[http://www.dnr.state.md.us/fisheries/snakeheadinfosheet.html] and
[http://www.fcsc.usgs.gov/Nonindigenous_Species/Snakehead1.pdf].

Rainbow Trout, *Oncorhynchus mykiss*. This species has been introduced widely outside its historic range along the North American Pacific Coast, and introduced populations have been implicated in the disappearance of native fauna (*e.g.*, aquatic invertebrates). Stocking of rainbow trout for sport anglers in high altitude lakes in areas such as Yosemite National Park has been a controversial practice because of the impact on native fauna. Rainbow trout have also hybridized with subspecies of cutthroat trout in Nevada and interior western states, disrupting native gene pools. For more information, see
[http://www.sw-center.org/swcbd/papers/trout.htm],
[http://research.nwfsc.noaa.gov/pubs/tm/tm37/cuttext.htm], and
[http://www.state.gov/g/oes/rls/rpts/ocns/2322.htm].

Lake Trout, *Salvelinus namaycush*. In 1993, lake trout were discovered in Yellowstone Lake in Yellowstone National Park, where they threaten native cutthroat trout. Lake trout probably entered Yellowstone Lake by illegal human introduction as early as the late 1970s or early 1980s. The lake trout's native range includes most of the northern-tier states from Maine to Minnesota and across Canada into Alaska. Tourism and sport fishing for native trout could be harmed by this introduction. Cutthroat trout in Yellowstone National Park are the focus of a recreational fishery valued at $36 million annually, as well as an important prey for species such as bald eagles and some grizzly bears during the cutthroat's spring spawning season. For more information, see
[http://www.yellowstoneriver.org/lake_trout_ynp.html] and
[http://www.personal.psu.edu/users/z/a/zak100/LKTcontrol.htm].

Coqui, *Eleutherodactylus coqui*. The coqui is a small nocturnal frog native to Puerto Rico, where it is a revered symbol of the island. It is active in trees in moist areas, and hides during the day under ground cover. It lays its eggs in any damp place. The eggs hatch directly into tiny tailed frogs, undergoing the normal tadpole stage of most frogs while still in the egg. Adult frogs reach 1-2 inches. They are active at night or on rainy or overcast days. Only males call, from a perch usually 3 to 6 feet about the ground; the common name is taken from the unusually loud

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[124] 67 *Federal Register* 48855-48864.

sound of this two-note call. Its primary means of transport is *via* the shipment of horticultural specimens. The species was introduced, probably by accident, at Fairchild Tropical Garden in Miami in the 1970s, and is still present in the area though apparently mainly in greenhouses. It may also be present around New Orleans. It is established in the Virgin Islands.

In the 1990s, it became established in Hawaii, to the tremendous annoyance of residents, due to the loud calls which can reach 100 decibels. Its broader effects probably include predation on local insect populations and therefore competition with other native insectivores, including birds. Since many resident Hawaiian species are already under threat from still more invaders (*e.g.*, malarial parasites, mongooses, rats, pigs, non-native birds, etc.), this competition for food could be especially threatening. The state government has asked for cooperation from the state's large horticulture industry in preventing further spread of the species. Caffeine (in a 99% pure and highly toxic form) is in experimental use as a control around non-food plants. For more information, see
[http://www.hear.org/AlienSpeciesInHawaii/species/frogs/]

Brown Tree Snake, *Boiga irregularis*. The brown tree snake was introduced to Guam where it is now extremely abundant and has damaged the electrical and telephone grids. It has preyed on several endemic Guamanian birds so severely as to cause their extinction in the wild. Estimated losses due to power outages alone on Guam are at least $1 million per year.[125] It poses a serious threat to Hawaii and its tourism industry, since snakes are not hesitant to enter homes or hotels; though their venom is weak, over 200 Guamanians have been bitten, usually when snakes crawled into sleepers' beds. Native Hawaiian birds, having evolved in a snakeless environment, would also be at serious risk (and Hawaiian non-native birds would enjoy yet another advantage over the native birds). The problems caused by this species are covered in CRS Report 97-507 ENR, *Non-Indigenous Species: Government Response to the Brown Tree Snake and Issues for Congress.* Also see [http://www.aphis.usda.gov/ws/btsproj.html], and for Hawaiian problems specifically, see [http://www.hear.org/index.html].

Indian Mongoose, *Herpestes auropunctatus*. In the late 1800s, sugar cane growers in Hawaii and Puerto Rico sought ways to control the damage that introduced rats were causing to the crops. In what would prove to be a misguided attempt at biological control, they imported the Indian mongoose, a small predatory mammal native to Asia. The mongooses failed to control the rats but instead decimated native birds and other species, probably causing the extinction of some. In Puerto Rico and other Caribbean islands, mongooses are a major vector for rabies, and in some parts of Hawaii, they damage papaya and banana crops. They now occur on four of the five major Hawaiian islands, Kauai being the only exception. Control efforts costing millions of dollars per year have so far not succeeded in eliminating mongooses from any of those islands.[126] For more information, see:
[http://www.columbia.edu/itc/cerc/danoff-burg/invasion_bio/inv_spp_summ/Herpestes_auropunctatus.html].

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[125] Pimentel report.

[126] Pimentel report.

Nutria, *Myocastor coypus*. Nutria (relatives of beavers) were introduced to the United States from South America in 1899 to stimulate the fur industry. Some animals escaped after a hurricane, and later when the industry failed, surplus animals were released. The highly prolific, semi-aquatic species is now established in 22 states, and has been sighted in many more. It has no natural enemies, and remaining fur trappers have not kept pace with its exploding population growth.[127] It has severely damaged marsh vegetation which causes conversion of heavy vegetation to open water, thereby removing nesting or overwintering habitat for many birds, and eliminating habitat critical to the juvenile stages of important commercial species such as shrimp, crabs, oysters, many species of young fishes, and others. It has been very destructive in Gulf Coast states and the mid-Atlantic states, primarily on the Delmarva Peninsula. After a hearing before the House Resources Committee (Ser. No. 105-97), Congress passed legislation (P.L. 105-332) to assist Maryland in controlling nutria populations. For more information, see [http://nas.er.usgs.gov/mammals/mammals.htm], or, for Blackwater National Wildlife Refuge (MD) specifically, see [http://www.pwrc.usgs.gov/resshow/nutria.htm].

[127] One reviewer, E.A. Allison of the University of East Anglia, reports that after a 30 year effort, the species was eradicated from marshes in that area of the United Kingdom. (Personal communication, May 1999.)

Appendix A: List of Acronyms

ACE	Army Corps of Engineers
ANS	Aquatic nuisance species
APHIS	Animal and Plant Health Inspection Service
ARS	Agricultural Research Service
ASPEA	Alien Species Prevention and Enforcement Act
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
BOR	Bureau of Reclamation
BWM	Ballast water management
BWT	Ballast water treatment
CDB	Convention for Biological Diversity
CDC	Centers for Disease Control and Prevention
CEC	Commission on Environmental Cooperation
CEQ	Council on Environmental Quality
CENR	Committee on Environment and Natural Resources Research
CFR	Code of Federal Regulations
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CSREES	Cooperative State Research, Education, and Extension Service
DOD	Department of Defense
DOI	Department of the Interior
EEZ	Exclusive Economic Zone
EIFAC	European Inland Fisheries Advisory Commission
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
ERS	Economic Research Service
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FHwA	Federal Highway Administration
FICMNEW	Federal Interagency Committee for Management of Noxious and Exotic Weeds
FS	Forest Service
FSA	Farm Service Agency
FWS	Fish and Wildlife Service
GISP	Global Invasive Species Program
GLERL	Great Lakes Environmental Research Lab
ICES	International Council for the Exploration of the Sea
ICSU	International Council of Scientific Unions
IMO	International Maritime Organization
IPM	Integrated pest management

IUCN	International Union for the Conservation of Nature
MARPOL	International Convention on Marine Pollution
MEPC	Marine Environmental Protection Committee
NANPCA	Non-indigenous Aquatic Nuisance Prevention and Control Act
NBIC	National Ballast Information Clearinghouse
NBII	National Biological Information Infrastructure
NEPA	National Environmental Policy Act
NISA	National Invasive Species Act
NISC	National Invasive Species Council
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOBOB	No ballast on board
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NSF	National Science Foundation
NSTC	National Science and Technology Council
NWRS	National Wildlife Refuge System
ORD	Office of Research and Development
OSM	Office of Surface Mining Reclamation and Enforcement
OSTP	Office of Science and Technology Policy
OTA	Office of Technology Assessment
P.L.	Public Law
PPA	Plant Protection Act
RAG	Removal of aquatic growth
SCOPE	Scientific Committee on Problems of the Environment
SERC	Smithsonian Environmental Research Center
UNESCO	United Nations Environment Programme the Secretariat for the Convention on Biological Diversity
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
USTR	United States Trade Representative
WBCA	Wild Bird Conservation Act
WS	Wildlife Services (in APHIS)

Appendix B: Federal Agency Funding for Invasive Species

FY2000-FY2003 Request ($ in thousands)

Agency	FY2000	FY2001	FY2002	FY2003 Request
Department of Agriculture				
Agricultural Research Service	74,716	81,207	107,886	95,889
Animal and Plant Health Inspection Service	664,045	956,082	825,387	915,485
Cooperative State Research, Education, and Extension Service	12,191	18,750	13,235	11,787
Economic Research Service	30	0	0	2,000
Farm Service Agency[128]	0	0	0	0
Forest Service	35,219	55,380	61,130	81,683
Natural Resources Conservation Service	1,600	1,600	1,545	1,313
Office of the Chief Economist[129]	258	438	438	438
Department of Commerce				
National Oceanic and Atmospheric Administration[130]	1,650	1,750	3,250	800

[128] The Farm Service Agency does not have funding for invasive species work. It only requires farmers signing up for conservation programs to control invasive species on the enrolled acres.

[129] The USDA Office of the Chief Economist advises the Secretary on the economic implications of Department policies, programs, and proposed legislation. These amounts represent the portion of the Office's budget allocated to economic analysis of invasive species.

[130] In addition to the funding shown, GLERL spends between $400,000 and $500,000 annually on invasive species from its base funds.

Agency	FY2000	FY2001	FY2002	FY2003 Request
National Sea Grant College Program[131]	3,000[132]	2,993	3,000	0
Department of the Interior				
Bureau of Indian Affairs[133]	1,978	1,994	2,007	2,012
Bureau of Land Management	7,950	8,930	9,160	8,200
Bureau of Reclamation	2,112	2,062	2,180	2,129
Fish and Wildlife Service	7,563	14,421	15,122	15,185
Geological Survey	5,184	7,600	7,800	7,300
National Park Service[134]	1,200	1,200	1,800	2,145
Office of Surface Mining Reclamation and Enforcement	0	10	25	50
Other Departments				
Army Corps of Engineers[135]	12,600	12,000	11,200	0
Department of State	0	12,149	12,248	12,000

[131] The Administration's FY2003 budget request proposed transferring the Sea Grant program to the National Science Foundation, and consequently, the request does not specifically include funding for invasive species activities. No FY2003 appropriations bill for the Commerce Department has yet been filed in the House, but the Senate bill (S. 2778) requires that Sea Grant remain in NOAA. (See CRS Report RL31309.)

[132] In addition, Sea Grant universities were calculated to have spent about $586,000 from core funds on invasive species research.

[133] This is the Noxious Weed Control program. Some weeds may be native to North America. The is no formal national program for control of non-native animals.

[134] NPS figures are for Exotic Plant Management Teams only. Other invasive species efforts (*e.g.*, for animals and some aquatic plants, as well as a few terrestrial plants) are funded as parts of the budgets of individual park system units. Aggregate figures for these efforts are difficult to obtain, but according to NPS officials represented about 18% of the NPS FY2002 budget of $18 million for the Natural Resource Challenge program.

[135] The Corps estimates that the figures for FY2000 to FY2002 are $12.6 to $22.6 million, $12.0 to $22.0 million, and $11.2 to $21.2 million, respectively. No figures are available for the FY2003 request.

Agency	FY2000	FY2001	FY2002	FY2003 Request
Coast Guard	3,997	4,092	4,052	4,093
Federal Aviation Administration	0	0	0	0
Federal Highway Administration[136]	100	275	60	n/a
Council on Environmental Quality[137]	0	0	0	0
Office of Science and Technology Policy	0	0	0	0
Office of the U.S. Trade Representative	0	0	0	0
Environmental Protection Agency	450	500	4,000	500
National Science Foundation	18,060	11,860	9,000[138]	8,000[139]
Smithsonian Institution	2,180	3,184	4,079	3,915
Total	**858,083**	**1,200,478**	**1,100,606**	**1,176,927**

n/a = not available

[136] Figures include only expenditures for research, conferences, and publications. Vegetation management is state-funded and the share of unmarked federal highway funds used is not known. Of the total shown over the 3 years, $325,000 was used for research, $50,000 for a field guide to invasive roadside plants, and $60,000 for a North American conference.

[137] For this and the following two agencies, it is essentially impossible to name a figure associated with invasive species. The difficulty lies in the diffuse and variable nature of their responsibilities.

[138] NSF estimates between $8 million and $10 million.

[139] NSF states the amount is dependent upon proposals received, but estimates that the figure will be between $8 million and $10 million.