

# PREVENTING THE SPREAD OF INVASIVE SPECIES



**T**he introduction of invasive species into marine and Great Lakes ecosystems costs the nation millions, or possibly billions of dollars a year in economic and ecological damage. A major source of aquatic nuisance species is the discharge of ballast water from ocean-going ships. Numerous federal agencies are involved in efforts to prevent the introduction of such species and many laws and regulations have been developed to combat the problem, but more needs to be done to reduce this threat. Preventing introductions of invasive species or limiting their impact, will require streamlined programs and increased coordination among agencies, establishment and enforcement of domestic and international ballast water management standards, an educated public, and adequate funding.

## Acknowledging the Problem

**T**he introduction of invasive species into ports, coastal areas, and watersheds has damaged marine ecosystems around the world, costing millions of dollars in remediation, monitoring, and ecosystem damage. Invasive species are considered one of the greatest threats to coastal environments,<sup>1</sup> and can contribute substantially to altering the abundance, diversity, and distribution of many native species.<sup>2</sup> Although not every non-native species becomes an invader (Box 17.1), the sudden availability of new habitat and absence of its natural predators can lead to runaway growth that pushes out other species. Unlike many forms of pollution that degrade over time, invasive species can persist, increase, and spread.

The cost to the U.S. economy of terrestrial and aquatic invasive species has been difficult to determine. Of the few studies that exist, one estimates the damages at \$137 billion a year.<sup>3</sup> Of the more than \$600 million spent in 2000 to address this problem, the U.S. Department of Agriculture (USDA) received approximately 90 percent for predominantly land-based efforts,<sup>4</sup> while less than 1 percent was dedicated to combating aquatic invasive species.<sup>5</sup> Yet the sea lamprey has decimated a Great Lakes fishery, and aquatic plants, such as hydrilla and water chestnut, have significantly disrupted navigation. One infectious oyster disease, commonly known as MSX and most likely introduced through the experimental release of a Japanese oyster to Delaware Bay in the 1950s,<sup>6</sup> has devastated populations of native oysters along the East Coast.

## Box 17.1 What Is an Invasive Species?

In this report, the meaning of *non-native species* is the same as the definition of *nonindigenous species* provided in the Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA), as amended by the National Invasive Species Act:

*“[A] nonindigenous species means any species or other viable biological material that enters an ecosystem beyond its historic range, including any such organism transferred from one country into another.”*

The term *aquatic invasive species* as used in this report is based on the definition of *aquatic nuisance species* provided in NANPCA:

*“[An] aquatic nuisance species [is] a nonindigenous species that threatens the diversity or abundance of native species or the ecological stability of infested waters, or commercial, agricultural, aquacultural, or recreational activities dependent on such waters.”*

Thus invasive species are a particularly harmful subset of all *non-native species* introduced into new environments.

The history of the European green crab in the United States illustrates the trajectory of many invasive species. Native to the coasts of the North and Baltic seas, the green crab has been introduced to new environments through ballast water discharge, use as fishing bait, and packaging of live seafood. The green crab was first seen in San Francisco Bay in 1989, and has now become widespread on both the Atlantic and Pacific coasts. A number of ecosystems invaded by this small crab have been significantly altered. It competes with native fish and bird species for food and may also pose a threat to Dungeness crab, clam, and oyster fisheries.

The problem of invasive species may be exacerbated by climate change. Warming temperatures can alter aquatic habitats and species distributions, making native populations more susceptible to invasion.

## Assessing Existing Approaches

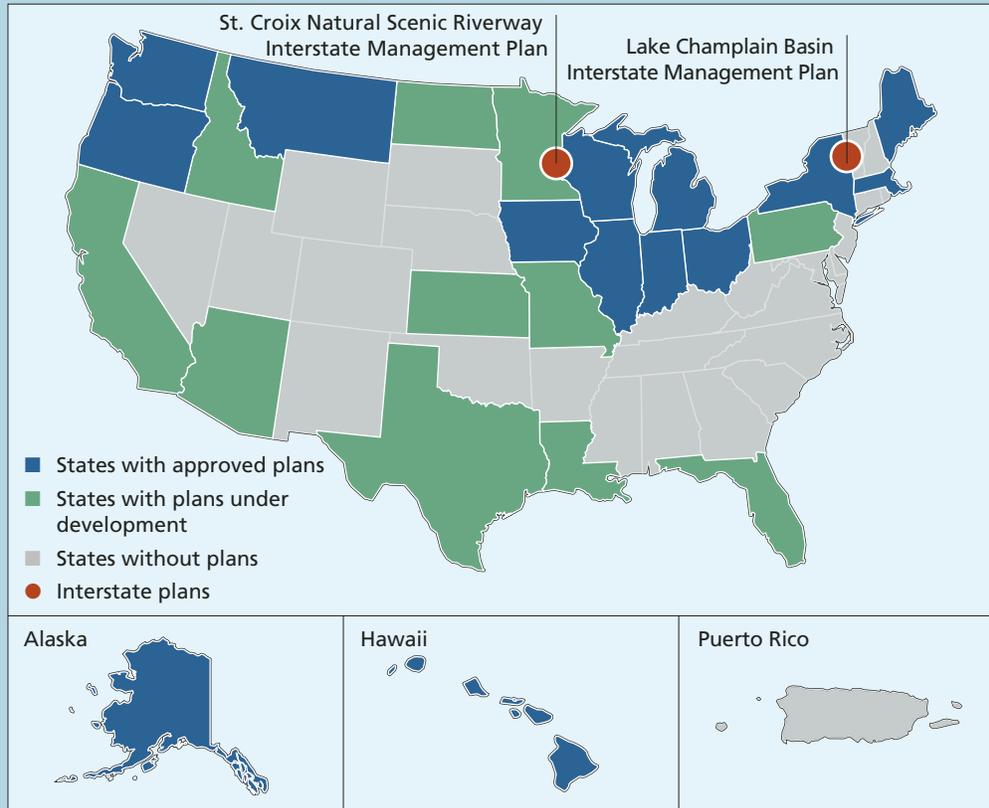
More than a decade has passed since the first legislation was enacted to combat invasive species, yet unwanted organisms continue to enter the United States where they can cause economic and ecological havoc. Invasive species policies are not keeping pace with the problem primarily because of inadequate funding, a lack of coordination among federal agencies, redundant programs, and outdated technologies.

### Federal Statutes

The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA), as amended in 1996 by the National Invasive Species Act, is the primary federal law dealing with aquatic invasive species and ballast water management. NANPCA established the Aquatic Nuisance Species Task Force, which includes representatives from the relevant federal agencies and thirteen nonfederal stakeholders. Co-chaired by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Fish and Wildlife Service (USFWS), the Task Force is responsible for facilitating cooperation and coordination among federal, regional, and state agencies. The legislation also addresses research, prevention, species control, monitoring, and information dissemination.

The Task Force encourages states to develop plans for managing invasive species, and NANPCA provides the appropriate federal agencies with authority to issue regulations to carry out their responsibilities under the law. To comply with NANPCA, the U.S. Coast

**Figure 17.1 Great Lakes States Take Lead in Implementing Aquatic Invasive Species Management Plans**



The Aquatic Nuisance Species Task Force encourages states to develop management plans for detecting and monitoring aquatic invasive species, educating the public, and encouraging collaborative mitigation efforts. Of the fourteen states that currently have plans approved by the Task Force, six border the Great Lakes. And while other coastal states such as California, Texas, Louisiana, and Florida are developing plans, the majority of East Coast states are not currently pursuing aquatic nuisance species management plans.

Source: U.S. Fish and Wildlife Service, Arlington, VA.

Guard has established regulations and guidelines to address introductions of non-native species through the uptake and discharge of ballast water from ships.

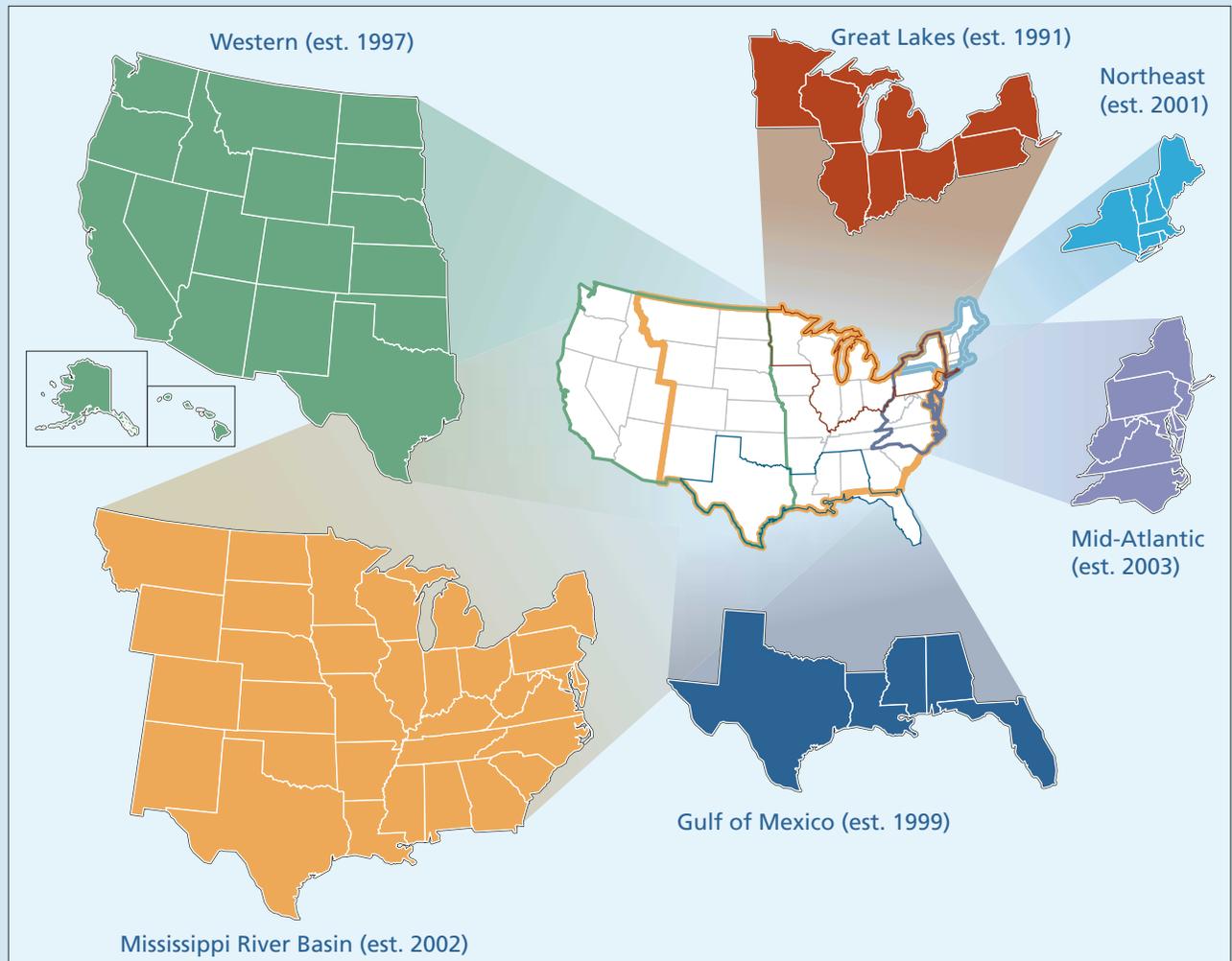
Resource allocation for managing invasive species varies widely among federal, state, and local agencies. While NANPCA authorizes federal funding to help states implement their approved Aquatic Nuisance Species Management Plans, the appropriation has historically been substantially less than the authorization and has not been effective in motivating states to complete management plans. Since 1996, when this provision was included in NANPCA, only fourteen states have established plans (Figure 17.1).

NANPCA also encourages the formation of regional panels, which operate under goals outlined in the Act. The panels develop priorities and working groups to explore invasive species issues applicable to their areas and make recommendations for regional action. Six regional panels have been established (Figure 17.2).

The National Invasive Species Council, consisting of ten federal departments and agencies, was established by executive order in February 1999 to provide national leadership on managing terrestrial and aquatic invasive species. In 2001, the Council produced a management plan with significant input from a nonfederal advisory committee.<sup>7</sup>

The Lacey Act allows the U.S. Department of the Interior (DOI) to regulate the importation of animals found to be injurious to wildlife. However, the Act is more often used to

Figure 17.2 Addressing Aquatic Invasive Species Regionally



Created under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990, six overlapping regional panels work to limit the introduction, spread, and impacts of aquatic invasive species in their waters.

Source: U.S. Fish and Wildlife Service, Arlington, VA.

respond to an existing invasive species problem than to promote proactive approaches for preventing their introduction.

The Plant Protection Act and animal quarantine laws authorize the USDA's Animal and Plant Health Inspection Service to prohibit certain plants and animals from entering the United States, and to require inspection, treatment, quarantine, or other mitigation measures. The Service can pre-clear shipments of certain organisms by requiring inspection and quarantine in the country of origin.

### State and Federal Programs

NOAA's National Sea Grant College Program, in cooperation with USFWS and the Aquatic Nuisance Species Task Force, coordinates and funds aquatic invasive species research, outreach, and education, and administers a research and development program in ballast water management technology. Other NOAA programs address shellfish diseases and threats to essential fish habitat, including the control and removal of invasive species.

The U.S. Army Corps of Engineers (USACE) has several programs that address the interactions between invasive species and federal navigation routes, including the

Aquatic Plant Control Program, the Zebra Mussel Program, and the Removal of Aquatic Growth Program. USACE is also authorized to implement a 50/50 federal cost share with state and local governments for managing invasive species in navigable waterways not under federal control.

The Federal Insecticide, Fungicide, and Rodenticide Act gives the U.S. Environmental Protection Agency (EPA) regulatory authority over the use of chemicals to combat invasive species. EPA may require an environmental assessment for invasive species control activities if these chemicals are involved. And DOI's National Wildlife Refuge System program reviews strategies and recommends pilot projects involving invasive species.

In addition to these federal programs, much of the actual monitoring, management, and control of invasive species falls under regional and state jurisdiction. The Great Lakes Panel on Aquatic Nuisance Species, convened in 1991 with membership representing the eight Great Lakes states, federal and regional agencies, tribal authorities, local communities, and user groups, continues its leadership role as a regional panel, supporting initiatives to prevent, detect, and respond to invasive species. Some states, such as California, have laws that address the illegal transport of certain species, the control of infected, diseased, or parasitized aquatic species, and the marine aquariums pet trade.

## Identifying Major Pathways for Introduction of Non-native Species

The discharge of ballast water is considered a primary pathway for introduction of non-native species. Other ship-related sources, such as sea chests (openings in ship hulls used when pumping water), ships' hulls, anchors, navigational buoys, drilling platforms, and floating marine debris, are also important. Other pathways include intentional and unintentional human introductions of fish and shellfish, and illegally released organisms from the aquaculture, aquarium, horticulture, and pet industries. There is also increasing concern that expanding trade through exotic pet dealers, including on the Internet, is exacerbating the invasive species problem, including the introduction of new diseases.<sup>8</sup> Although not all non-native species become invasive (threatening native species, the larger ecosystem, or commercial, agricultural, or recreational activities) their potentially devastating effects call for significant measures to restrict introduction as much as possible.

### Ballast Water

Ships carry ballast water to aid in stability, trim (or balance), and structural integrity. An estimated 7,000 species are carried in ships' ballast tanks around the world.<sup>9</sup> While most of them perish during the voyage, even a few survivors can be enough to establish a reproductive population when discharged into a waterway. Under certain conditions, non-native species can compete with native species and become pests in their new environment.

Currently, ships entering U.S. waters with no ballast on board are exempt from some management requirements. However, even seemingly empty ballast tanks often contain residual water and sediments that can release non-native species to receiving waters when the ships take on and discharge water during a coastal or Great Lakes passage.

Intercontinental voyages are not the only way to introduce non-native species through ballast water discharge. The spread of non-native species from one port to another within U.S. waters is of increasing concern on the East and West coasts. Unfortunately, the Coast Guard's jurisdiction is limited to vessels entering U.S. waters from outside the exclusive economic zone (EEZ). Recently enacted law in California authorizes state authorities to order ballast water discharge in certain areas outside state waters prior to docking at California ports. Other coastal states are also considering taking action.

## Global Trade in Marine Organisms

Human releases of living marine resources serve as another pathway for the introduction of non-native species. Live fish and shellfish importers, aquaculture facilities (discussed in Chapter 22), and retail pet stores routinely transport, raise, and sell non-native species in the course of business. Along the way, specimens can escape, be disposed of in an unsafe manner, or unknowingly serve as a vector for the introduction of other organisms. Live worms and other bait, packing material, seaweed, and seawater used to transport living organisms may also introduce non-native species into new environments.<sup>10</sup>

## Making Prevention the First Line of Defense

Recognizing the economic and biological harm caused by invasive species, and acknowledging the difficulty of eradicating a species once it is established, aggressive steps should be taken to prevent such introductions.

### Ballast Water Management

Exchanging ballast water in the middle of the ocean to reduce the risk of transferring organisms from one ecosystem to another is the primary management tool currently available for ships to control the introduction of invasive species, although this approach is not helpful in controlling domestic port-to-port contamination.

The Coast Guard began implementing ballast water management regulations in 1993 and mandated ballast water exchange for vessels bound for the Great Lakes. However, the lack of similar requirements across the nation led several states, including California, Oregon, and Washington, to also make ballast water exchange mandatory for ships entering their state waters. As a result, ships entering U.S. waters have to contend with different requirements depending on their port of entry. To strengthen invasive species management, the Coast Guard has issued regulations mandating ballast water exchange by vessels entering the United States from outside the EEZ.

However, new technologies may also provide alternatives to mid-ocean ballast water exchange by finding ways to eliminate stowaway species in ballast water. To encourage development, testing, and adoption of these technologies, the Coast Guard is establishing an enforceable treatment standard and a shipboard testing program. This approach will establish a required level of protection against the spread of non-native species and speed progress toward an ultimate goal of preventing all introductions of organisms, including bacteria and viruses.



Invasive species alter marine habitats and can interfere with fishing, aquaculture, recreation, and other coastal and offshore activities. This sea squirt, native to Europe but seen here in California, reproduces rapidly and has no natural predators in this country.

Coastal and Marine Geology Program, USGS

### Recommendation 17-1

The U.S. Coast Guard's national ballast water management program should include a number of important elements: uniform, mandatory national standards which incorporate sound science in the development of biologically meaningful and enforceable ballast water treatment; a process for revising the standard to incorporate new technologies; full consultation with the U.S. Environmental Protection Agency, both during and after the program's development; and an interagency review, through the National Ocean Council, of the policy for ships that declare they have no ballast on board.

Investments in new treatment technologies, including technologies to minimize the uptake of sediments in ships' ballast tanks, will help avoid the high cost of eradicating or managing invasive species. Although NANPCA directed DOI and NOAA, in cooperation with the Coast Guard, to conduct projects that demonstrate technologies and practices for preventing introductions through ballast water, this program has been chronically underfunded. The current limited program supports some technology development, but is unable to demonstrate the real-world effectiveness of these technologies for treating ballast water. To ensure ongoing improvements, government and industry will need to work together to develop and test innovative treatment technologies that are environmentally and economically viable.

### **Recommendation 17-2**

The National Ocean Council should commission a credible, independent, scientific review of existing U.S. ballast water management research and demonstration programs and make recommendations for improvements.

The review should consider the following issues:

- how federally funded research and demonstration programs can best promote technology development, support on-board ship testing, and move technologies from research to commercial use.
- what the best role is for industry and how industry can be engaged in onboard testing of experimental ballast water management technologies.
- what kind of peer review process is needed for scientific oversight of technology development, selection of demonstration projects, and testing of experimental treatment systems.
- what is an adequate funding level for a successful ballast water research and demonstration program.

## **Controlling Other Pathways**

Ballast water is a clearly identifiable source that can be managed through traditional regulatory means, but other sources of invasive species, such as the shellfish importing, aquaculture, aquarium, horticulture, and pet industries, are far more diffuse and less amenable to federal controls. Preventing introductions through these pathways will require a mix of federal and state legislation, and public education.

Public education is a vital component of a prevention strategy. Individuals must understand that their actions can have major, potentially irreversible, economic and ecological consequences. Increasing the public's awareness, and suggesting actions that boaters, gardeners, scuba divers, fisherman, pet owners, and others can take to reduce introductions, can help prevent the spread of invasive species.

Currently, a number of unconnected education and outreach programs exist—generally focusing on individual species—but a more coordinated, national plan is needed. As international markets continue to open and Internet use grows, access to the purchase and importation of non-native animals and plants from all over the globe is likely to increase. Some industry representatives have expressed concern that efforts to prevent introductions of non-native species may interfere with the flow of free trade. The need to protect public health and ecosystems will have to be balanced against these interests.

### **Recommendation 17-3**

The U.S. Departments of Agriculture, Commerce, the Interior, and Homeland Security should more actively employ existing legal authorities to prohibit imports of known or potentially invasive species. The National Ocean Council should recommend any changes to such legal authorities that might result in more effective prevention efforts.

## Recommendation 17-4

The National Ocean Council, working with the Aquatic Nuisance Species Task Force and the National Invasive Species Council, should coordinate public education and outreach efforts on aquatic invasive species, with the aim of increasing public awareness about the importance of prevention.

The education and outreach effort should be pursued on several fronts:

- connect local, regional, and national outreach and education efforts, including recommendations from the U.S. Invasive Species Management Plan and programs initiated by industries that deal with non-native species.
- provide the public, importers and sellers, pet store and restaurant owners, divers, and others with information about the harm caused by invasive species and safer methods of shipping, owning, and disposing of non-native species.
- require the aquaculture, horticulture, pet, and aquarium industries to clearly inform customers of the potential hazards of releasing non-native species.

## Accelerating Detection and Response

Only the most draconian prevention strategy could hope to eliminate all introductions of non-native species and thus prevent even the possibility of a problem. Yet no effective mechanism is in place for detecting and rapidly responding to new aquatic invasive species. Currently, both states and regional panels are encouraged to develop detection and rapid response plans; however jurisdictional questions and limited resources have hindered development and implementation of such plans.

Of the approximately \$149 million in federal funding spent in 2000 for invasive species rapid response, the U.S. General Accounting Office estimates that USDA spent about \$126 million on threats to crops and livestock.<sup>11</sup> In contrast, DOI and NOAA together spend about \$600,000 annually on responses to threats from aquatic invasive species. The inadequacy of this funding level becomes even more obvious when the costs of a single eradication effort are considered.

In June 2000, *Caulerpa taxifolia*, dubbed a “killer algae,” was discovered near a storm drain in the Agua Hedionda Lagoon in southern California. Efforts to eradicate the algae, primarily by injections of chlorine under tarps placed over the infested areas, were overseen by the Southern California Caulerpa Action Team. The initial eradication effort cost \$500,000, with another \$500,000 allocated for surveys and treatment of remaining infestations. The eradication efforts will not be deemed successful until five years pass, during which an average of more than \$1 million per year will be spent for periodic surveying and spot treatments.<sup>12</sup>

Other examples abound. Control of the invasive zebra mussel, an organism first introduced through ballast water discharge, cost municipalities and industries almost \$70 million a year between 1989 and 1995.<sup>13</sup> Over the next ten years, the zebra mussel invasion will cost an estimated additional \$3.1 billion, including costs to industry, recreation, and fisheries. Florida’s ongoing cost of managing the invasive hydrilla plant is more than \$17 million a year.<sup>14</sup>

*We must increase efforts to prevent species invasions, exterminate and control populations that become established, and limit their spread via waterways that connect watersheds. Just as extinction of species is forever, so too is the establishment of these invaders.*

—William F. Hartwig,  
Director, Region 3, U.S.  
Fish and Wildlife Service,  
testimony to the Commission, September 2002

## Recommendation 17-5

The National Invasive Species Council and the Aquatic Nuisance Species Task Force, working with other appropriate entities, should establish and implement a national plan for early detection of invasive species and a well-publicized system for prompt notification and rapid response.

The plan should:

- provide risk assessments for potentially invasive species, including possible pathways of introduction.

- conduct a comprehensive national biological survey and monitoring program for early detection, building upon recent progress in this area by academia, the U.S. Geological Survey, the National Oceanic and Atmospheric Administration, and the U.S. Environmental Protection Agency.
- determine the threshold needed to trigger a rapid response and develop environmentally sound rapid-response, eradication, and control actions.
- designate resources for implementing surveys and eradication programs.
- develop partnerships among government and industry to fund and implement response actions.

## Improving the Control of Invasive Species

As biological invasions continue, there is a pressing need to improve the control of invasive species by reducing the overlaps and redundancies caused by the involvement of multiple agencies with insufficient interagency coordination. More than twenty federal entities, under ten departments or independent agencies, have some responsibility for invasive species management.

### Coordinated Action

The Aquatic Nuisance Species Task Force and the National Invasive Species Council have made a start in coordinating federal agencies and states. Yet different priorities among the agencies constrain full cooperation in funding and implementing invasive species programs. The ability to establish cross-agency goals is limited, and neither the Task Force nor the Council has established clear performance-oriented objectives in their work plans.

Management of invasive species is particularly complicated because the initial source of the non-native species, the path of introduction, and the resulting ecological and economic impacts may be quite far removed from each other. This increases the need for close coordination among different jurisdictions. Although national standards are impor-

### Box 17.2 Federal Departments and Agencies with Roles in Invasive Species Management

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| <ul style="list-style-type: none"> <li>• <b>U.S. Department of Agriculture</b><br/>Agriculture Research Service<br/>Animal and Plant Health<br/>Inspection Service<br/>Cooperative State Research,<br/>Education, and Extension Service<br/>Economic Research Service<br/>Farm Service Agency<br/>Forest Service<br/>Natural Resources Conservation Service</li> <li>• <b>U.S. Department of Commerce</b><br/>National Oceanic and Atmospheric<br/>Administration</li> <li>• <b>U.S. Department of Defense</b><br/>U.S. Army Corps of Engineers</li> <li>• <b>U.S. Environmental Protection Agency</b></li> </ul> | <ul style="list-style-type: none"> <li>• <b>U.S. Department of Homeland Security</b><br/>U.S. Coast Guard<br/>U.S. Customs and Border Protection</li> <li>• <b>U.S. Department of the Interior</b><br/>Bureau of Indian Affairs<br/>Bureau of Land Management<br/>Bureau of Reclamation<br/>U.S. Fish and Wildlife Service<br/>U.S. Geological Survey<br/>Minerals Management Service<br/>National Park Service<br/>Office of Insular Affairs</li> <li>• <b>National Science Foundation</b></li> <li>• <b>Smithsonian Institution</b></li> <li>• <b>U.S. Department of State</b></li> <li>• <b>U.S. Department of Transportation</b><br/>Federal Highway Administration</li> <li>• <b>U.S. Department of the Treasury</b></li> </ul> |
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tant for ballast water, coordinated regional or state actions may be more appropriate for other pathways. The Task Force promotes the development of state plans, but has had only marginal success in bringing resources to the regional panels and local authorities for implementation.

While most management plans focus on unintentional introductions, a noticeable gap in regulatory authority exists in the area of intentional introductions of non-native species for commercial purposes. A recent example is the controversial proposal to introduce a Chinese oyster (*Crassostrea ariakensis*) into the Chesapeake Bay to replace the vanishing native oyster and revive the moribund oyster industry there. A 2003 National Research Council report concluded that a rigorous, consistent risk assessment protocol will be needed to evaluate such proposals, but there is currently no authority or mechanism for conducting such assessments.<sup>15</sup>

Clearer policies will also be necessary as the aquaculture industry expands. Voluntary self-regulation by participants in the aquaculture industry is likely to be ineffective because the costs of control are relatively high, it is difficult to trace an invasive species to a specific source, and the negative consequences of an introduction are felt by those outside the industry. (The need for a marine aquaculture regulatory regime is discussed in Chapter 22.)

### Recommendation 17–6

The National Ocean Council (NOC) should review and streamline the current proliferation of programs for managing aquatic invasive species in marine environments, and should coordinate federal, regional, and state efforts. Consolidated plans should be implemented to develop risk assessment and management approaches for intentional and unintentional species introductions that minimize the potential of invasions at the lowest cost.

Specifically, the NOC should:

- review the effectiveness of existing programs and legal authorities and clarify the lines of responsibility and enforcement authority, including responsibility for intentional introductions of non-native species.
- develop long-term goals and measures for evaluating effective performance.
- estimate funding needs to prevent the introduction of invasive species, including support for regional and state programs.
- determine whether, in the long term, a single agency should be charged with preventing the entry of, monitoring, and containing invasive species in coastal and marine waters.

## International Partnerships

The movement of invasive species is clearly a global concern, and successful programs will require strong international cooperation and coordination. In 2004, the International Maritime Organization (IMO) adopted the International Convention for the Control and Management of Ships' Ballast Water and Sediments, designed to control the spread of invasive species carried in ships' ballast water. The convention contains requirements for ballast water management, but also allows countries to establish additional, more stringent national or regional standards. The implications of this new convention for U.S. ballast water policy are currently under discussion. The United States should continue to pursue national legislative and regulatory remedies to limit ballast water introductions into the Great Lakes and U.S. coastal waters, while recognizing that international solutions provide the best long-term strategy for addressing the global threat presented by ships' ballast water.

The United States can work with its closest neighbors, Canada and Mexico, to develop a North American strategy, craft regional invasive species management programs, and encourage key commercial sectors to develop voluntary codes of conduct and other self-regulatory mechanisms. Based on national and regional experiences, the United States can then promote international progress through appropriate conventions and treaties.

## Recommendation 17–7

The United States should take a leading role in the global effort to control the spread of aquatic invasive species by working internationally to develop treaties, agreements, and policies to minimize the introduction and establishment of such species.

## Research Needs

The study of aquatic invasive species in marine environments is a relatively new research area. Although invasive species have dramatically changed ecosystem structures, threatened native species, and caused hundreds of millions of dollars in economic damage, little is understood about how or why certain species become invasive, what pathways of introduction are most important, and whether certain factors make an ecosystem more susceptible to invasions. Currently, U.S. investment in research on invasive species, monitoring to detect invasions, and development of new techniques for identification and eradication falls far short of the economic cost to the nation caused by this problem. Enhanced monitoring to detect invasive species should be part of the national monitoring network described in Chapter 15.

## Recommendation 17–8

The National Ocean Council should coordinate the development and implementation of an interagency plan for research and monitoring to understand and prevent the spread of aquatic invasive species. The results should be used to improve management decisions and avoid future economic losses.

New research and monitoring efforts should focus on:

- gathering baseline taxonomic information and strengthening taxonomic skills; performing quantitative assessments of ecosystems; identifying invasive pathogens and vectors of introduction; and determining how invasive species disrupt ecosystem functions.
- understanding the human dimensions behind species introductions, including human behavior, decision making, and economics.
- developing new options for minimizing invasions, including innovative technologies, and translating these findings into practical policy options for decision makers.

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