Testimony by David M. Lodge

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Madame Chairwoman and Subcommittee members, I am honored to have the opportunity to participate in this hearing. I thank the subcommittee, especially Chairwoman Johnson, for the invitation to testify.

As you may know from my resume, I come to the issue of invasive species from the perspective of an active researcher in this field and from my experiences at the science-policy interface. I have been working on invasive species for 24 years. I am the Director of the Center for Aquatic Conservation and a Professor of biology at the University of Notre Dame. My colleagues, collaborators, and I have on-going research that includes the following topics: (a) quantifying the probability of ship-related releases of invasive species by analyzing global shipping patterns, sampling organisms in and on ships, developing genetic probes for detecting harmful organisms in ballast water, and modeling the growth of small, newly introduced populations; (b) forecasting the spread and impact—both environmental and financial--of zebra mussel, Eurasian river ruffe, and other organisms introduced originally by ships into the Great Lakes; (c) measuring and controlling the impact of invasive rusty crayfish; (d) developing species screening protocols, focused on fishes, mollusks, plants and other organisms in the Great Lakes and other U.S. waters; and (e) combining economic and ecological risk analyses to guide allocation of resources among management options. I am a past Chairman of the national Invasive Species Advisory Committee.

The round goby—a fish story with big impacts

Let me begin by summarizing the many detrimental impacts of the round goby, a small to medium-sized fish from Eurasia that lives on the bottom of lakes and rivers. In North America, the first round goby was caught in Lake St. Clair in 1990. The species had been introduced via the discharged ballast water of a ship. Over the ensuing decade, round gobies spread throughout the Great Lakes, escaped down the Chicago Sanitary and Ship Canal, and under their own steam are now on their way toward colonizing the Mississippi River basin. The addition of just one species to North America matters for several related reasons.

In southern Lake Michigan, where recreational and commercial anglers used to harvest vast numbers of prized native yellow perch, now only invasive round gobies are caught. In the lakeside economically depressed areas in northern Indiana and southwestern Michigan, where poor boys and girls used to be able to catch their dinner off the breakwaters, fishing is now futile, unless they want round gobies on the menu. I've had this experience myself: pulling in small and useless goby after goby, with not a single native or valuable fish species in hours of fishing. Why? Because round gobies eat the eggs and fry of smallmouth bass and other highly valued fishes, out-compete valuable fishes for food, and out-compete native bottom-dwelling fishes for shelter. Finally, increasing evidence suggests that the microorganism that causes botulism occurs in round goby because they consume lots of zebra mussel and quagga mussel, in which the botulinum toxin accumulates. I'll have more to say later about these mussels, which are other bottom-dwelling invasive species. Botulism in turn has caused massive die-offs in lakes Erie and Ontario of sport fish and especially of water birds that consume

round gobies and other affected fish species. A potential threat exists to humans that consume these fish, but so far there are no known cases of human poisoning. For similar reasons, PCBs and heavy metals bioaccumulate in zebra mussel, and also accumulate further in the fishes that eat them. Humans must now limit their consumption of fishes to avoid PCB and heavy metal poisoning (Kwon et al. 2006). Accumulating toxins in Great Lakes invasive species are potentially an ecological time bomb.

Hence the impacts of just one species added to the Great Lakes have resulted in large environmental and financial costs, as well as threats to human health. These costs are still increasing as round gobies become more abundant within the Great Lakes, and the damages are spreading as the fish moves south in the Mississippi River basin and elsewhere. As we talk today, the ranges and abundances of round gobies and many other species are increasing. Given the long-term damages that will continue from these species, investments in prevention efforts are likely to bring large net returns to society.

Shipping as one of several major pathways of aquatic invasions

I could continue with stories about the impact of many, many more invasive species in terrestrial, marine, and freshwater ecosystems. Everywhere biologists look, we find more and more alien species, with the total number of alien species increasing over time (Ricciardi 2006, Cohen and Carlton 1995, Baltic Marine Biologists 2005). Perhaps more important than the number of species is the fact that in many situations the abundance of these aliens reaches extremely high levels--like that of round gobies and zebra mussels—so that there is literally very little room left for native species, and the total environmental and financial impact is very high. Each of these species is fascinating biologically, with its own idiosyncrasies. Thus I could go on and on telling you about the 184 alien species known to exist in the Great Lakes, but I won't for two reasons. We don't have time and we would lose the forest for the trees—or 'lose the lake for the species,' if you will. What is more important for today, and for using science to inform a policy discussion, is to get the big picture. And the first brushstroke in that big picture is to put shipping in the context of the other pathways by which alien species are introduced.

Shipping is only one of several major pathways by which alien species are introduced into the nation's ecosystems (Lodge et al. 2006). If we narrow our focus to the Great Lakes and neighboring waterways, shipping has historically accounted for about one-third to two-thirds of freshwater alien species (Mills et al. 1993). The most recent tally suggests that shipping currently accounts for about 70% of alien species discovered in the Great Lakes since ocean-going ships gained access to the upper Great Lakes in 1959 (Ricciardi 2006). It is important, therefore, to focus considerable attention on shipping. It is also important to recognize that, without more effective policies for multiple pathways, species have been and will continue to be introduced via other pathways, including dispersal through canals; stocking by private and public agencies; aquaculture escapes; the aquarium trade; the watergarden trade; the live bait trade; the biological supply trade; and the live food trade.

For the purposes of today's hearing, though, I'll focus the rest of my comments on shipping as a pathway for the introduction of aquatic alien species in the Great Lakes, and the impacts of those species.

Ships as pathways—ballast water and hull fouling

Ships are huge, floating aquaria, with entire ecosystems of mud and water and organisms inside. For example, bulk carriers can carry 100,000 m^3 of ballast water, equivalent to 40 Olympic size swimming pools. Dr. James Carlton has estimated that 5000-8000 species of organisms are in transit daily in the ballast tanks of ships.

Of the 184 alien aquatic species known in the Great Lakes, about 55 are attributable to release in the ballast water of ships since the opening of the St. Lawrence Seaway in late 1950s, with another four species attributable to dispersal through shipping canals (Ricciardi 2006). Of the 55 species attributed to ballast water release, 26 are free-living animals; most of the rest are algae, protozoans, and parasites of fish. The rate at which these animal species have been discovered has increased in recent years (Holeck et al. 2004, Drake et al 2005). I believe that reflects an increasing invasion rate. But we cannot be sure to what extent this increased discovery rate results from changes in sampling effort by biologists, increases in populations of species that were introduced and established years ago (and therefore only now detected), or a recent increase in the actual number of species introduced and established (Costello et al. 2007). What we know for certain is that these numbers are generally underestimates: monitoring efforts are few and poorly funded, and we are far more likely to discover large species rather than microorganisms, including pathogens and parasites. No doubt there are many more alien species in the Great Lakes than we know about (Costello et al. 2007). In any case, a novel alien animal species is now discovered about every 8 months in the Great Lakes, and we know that many additional novel species are being introduced every year even if they don't all establish self-sustaining populations (Drake & Lodge 2007).

Until recently, it has been assumed that all species introduced recently by ships into the Great Lakes were released in ballast water. However, in saltwater ecosystems, about one-half of ship-related invasions result from species transported on the hulls of ships. Very recent evidence suggests that hull fouling may be important in the Great Lakes also. From samples scraped from the hull of one ship that entered the St. Lawrence Seaway, my collaborators and I estimated that at least 100-200 different kinds of organisms were living on the hull. We identified two species of freshwater copepods never before observed in the Great Lakes. To my knowledge, this is the only ship in the Great Lakes whose hull has been sampled by biologists. Because ships that enter the Great Lakes have been in salt water for days or weeks, hull fouling is likely to be less important than for saltwater ecosystems, but these recent results suggest that we cannot continue to ignore the threat of hull-fouling organisms in the Great Lakes. At least for badly fouled ships, like the one we sampled, the number of species on the hull is of the same order of magnitude as the number of species typically sampled in ballast water.

Without additional policies, ships--these big floating aquaria--will cause increasing invasions around the world. For the Great Lakes, we have not begun to exhaust the supply of species native elsewhere in the world that would thrive in the Great

Lakes. For most of the history of Great Lakes shipping, ships have come from northern European ports, especially from the Baltic Sea. In addition to commercial goods they have intentionally delivered, these ships have also delivered species occurring in the Baltic Sea, which ranges from salty to fresh. And not all of the species occurring in the Baltic Sea originated in the Baltic Sea. Many invaded the Baltic decades or centuries ago from more southerly parts of Eurasia via canals and commercial vessels moving north through Europe. Thus the Great Lakes have received many species from the Baltic that came originally from the Black and Caspian seas region. As the number, size, and speed of ships in the growing network of global shipping increases, we can expect that many species will colonize many of the world's ports, even those not directly linked. It is useful to think of the ports of the globe as stepping stones; if a species invades one port, it is more likely to invade another. If shipping continues in the Great Lakes, then, we can expect to discover more and more species in future from places other than the Baltic and Eurasia.

Impact of ship-borne alien species in the Great Lakes

No comprehensive analysis of the impact on the Great Lakes region of ship-borne alien species exists. A group of us, including economists and biologists, are in the process of conducting such a study, with support from NOAA Sea Grant and EPA. What I can offer today is a summary of the state of our analysis, including some examples from the 26 alien animal species. At least 40% of the 26 known alien animal species cause undesirable impacts, either in the Great Lakes (although many have not been in abundance very long) or in similar freshwater environments. Because these species cause net negative impacts, we refer to them as invasive species. These damages include environmental change; loss of native biodiversity, including reductions in the health of highly valued fish and wildlife; threats to human health; and direct financial impact on industry and consumers. The health of our ecosystems—and therefore our well-being—is at stake.

In my opening comments, I offered the example of round goby, which has harmful impacts on native biodiversity, including commercially and recreationally valuable fishes, and which likely caused botulinum poisoning of 100s-1000s of water birds in some years. In the table below, I summarize the available data on the net negative impacts of round goby and seven other invasive species. These include the best documented species. We know very little about the impact of most species, especially many of the algae, protists, and parasites. It is not safe to assume, however, that they have no impact; rather we know so little because so little effort is devoted to learning about them. Therefore the impacts summarized in the table are a bare minimum of the aggregate impacts of ship-borne alien aquatic species in the Great Lakes.

It is instructive to examine two of the listed species in more detail, zebra mussel and quagga mussel. Their impacts are the best documented of any species listed, for two reasons. First, they have large, direct, financial impacts on industry. Second, zebra mussels were the first discovered among those listed, in the mid 1980s. So they've had more time to express their impacts. Like round gobies, both these mussel species originated in Eurasia. These two bivalve species look very similar; even biologists have

difficulty distinguishing them. But they differ somewhat ecologically: quagga mussel thrive in deeper portions of the Great Lakes and on softer sediments than do zebra mussel.

Preliminary analysis of net negative impacts of selected ship-borne invasive species: 1=low impacts; 3=high impacts; blank=no documented impacts.

	Native biodiversity	Infra-structure	Commercial fishing	Navigation	Recreation	Human health
Round goby[1]	2		1		2	1
Eurasian ruffe[2]	1		1		1	
NZ mud snail[3]	1?	1?				
Amphipod[4]	1					
Spiny water flea[5]	2				1	
Fish hook water flea[6]	1				1	
Quagga mussel[7]	2	2	2	1?	2	
Zebra mussel[8]	3	3	2	1	2	1

[1]*Neogobius melanostomus*; [2]*Gymnocephalus cernuus*; [3]*Potamopyrgus antipodarum*; [4]*Echinogammarus ischnus*; [5]*Bythotrephes longimanus*; [6]*Cercopagis pengoi*; [7]*Dreissena bugensis*; [8]*D. polymorpha*

The direct financial impacts of zebra and quagga mussels result from the mussels' habit of gluing themselves to any hard surface, including the inside of water intakes. Thus any municipality or industry that has intakes in a lake or river infested with zebra mussel has had to respond with some combination of control efforts, preventive maintenance, infrastructure redesign, and lost production. The best available data, now more than 10 years old, add up to annual expenditures in the Great Lakes region of at least $150 million in current dollars (O'Neill 1996). The nuclear power plant closest to my home spends between $1-2 million per year in response to zebra mussel. These costs are probably dramatic underestimates of financial damage and certainly do not include either the environmental damages or damages to commercial and recreational fishing.

Damages to fisheries are now well documented in the Hudson River (Strayer et al. in press), and strongly implicated in the Great Lakes through a series of interactions in the food web. Where the mussels become abundant in deeper waters the native amphipod (*Diporeia*) disappears. The amphipod, in turn, was the major food source for highly valued native whitefishes, the catches for which have declined by about 70% since the mid 1990s (Hoyle et al. 1995). In shallower waters, large changes in the abundance of many native organisms also occur, with, for example, the large native clams driven to local extinction.

The feces and other egesta of the invasive mussels accumulate into thick layers of organic matter that become anoxic, making them a great environment for the bacterium *Clostridium botulinum*, which manufactures a toxin that bioaccumulates in zebra and quagga mussels, and is then passed to round gobies that eat the mussels, and thence to fish like yellow perch and smallmouth bass that eat the round gobies and that are highly valued and consumed by people (Yule et al. 2006). The fish are also consumed by loons, ducks and other water birds, which then succumb to botulinum poisoning. Especially in lake Ontario and Erie, where vast numbers of zebra mussels exist in shallow waters, die-offs of 100s-1000s of water birds have increased in recent years.

Finally, the mussels are also strongly associated with increasingly frequent and severe blooms of harmful bluegreen algae, especially in the shallower, more productive parts of the lower Great Lakes. These blooms of *Microcystis* create taste and odor problems in drinking water, which reduce human satisfaction and/or require increased water treatment costs. I do not know of another region of the country where so many people withdraw drinking water from sources into which ballast water is dumped.

Thus, only two invasive mussels, especially in concert with other invasive species like round gobies, have produced a number of strong and harmful changes to the Great Lakes. Shipping brings with it a tax in the form of the damages done by invasive species—a tax that was formerly hidden but is increasingly obvious and large.

Damages from invasions in the Great Lakes—a threat to nation's freshwaters

These damages are irreversible to a large degree. In the context of endangered species, you've probably heard it said that "extinction is forever." Unfortunately, it is also usually true that invasion is forever. Biological invasions are the least reversible form of pollution. In contrast, most other forms of pollution--like the nitrogen and sulfur compounds of air pollution, the CFCs that destroy ozone, and PCBs—degrade or get buried (unless they are resurrected by invasive mussels), and the problems they cause decline eventually, if only we stop adding molecules of them to the environment. Chemical pollutants, in other words, do not reproduce; species do. Even if we stop adding individual round gobies and zebra mussels to Lake Michigan, their populations and those of many other invasive species will continue to grow, they will continue to spread throughout the Mississippi River basin and across the continent, and their environmental and economic damage will grow exponentially.

For example, in a soon-to-be-published report (Bossenbroek et al. 2007), we predicted that Lake Mead would be the most likely waterway west of the 100th Meridian to be colonized by invasive mussels. We made that prediction based on modeling efforts based on two perspectives: Lake Mead offers habitat suitable for zebra mussels, and many boaters from infested waterways in the Midwest visit Lake Mead. Some accidentally carry mussels on or in their boat or trailer. Before our paper was in print, quagga mussels were discovered in early January 2007 in Lake Mead and other locations on the Colorado River. As the mussels increase in abundance, large environmental and financial damages will ensue in the West as they have in the Midwest. In addition, other western waterways are now at a much higher risk of invasion because there are source populations of mussels nearby. All these impacts, including those yet to come

throughout the west, are ultimately caused by ocean-going ships bringing species into the Great Lakes.

If releases of organisms from the shipping pathway are not managed more effectively in future, many more invasive species will unfortunately be following those that I've talked about today—into the Great Lakes and eventually throughout the waterways of North America. In the long run, greater investments in management of the ship pathway will be far cheaper than continually reacting forever to new invasions.

Thank you again for the opportunity to offer my thoughts on the impact of invasions in the Great Lakes.

Please enter my entire written and oral testimony into the published record. I look forward to responding to your questions.

Additional sources

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